Appendix E2. b – Restoration Plans and TMDLs (Restoration Plans)

February 21, 2020

VIA Email

Maryland Department of the Environment
Integrated Water Planning Program
1800 Washington Boulevard
Baltimore, Maryland 21230

Subject: Swan Creek Restoration Plan for Sediment

As requested in MDE's letter dated September 19, 2019, Harford County has summarized responses to MDE's letter dated May 3, 2019. Those point by point responses are enclosed.

Harford County appreciated the opportunity to discuss comments in person with MDE on July 26, 2019 and welcomes similar meetings in the future.

If you have any questions, please contact me at (410) 638-3217 extension 1176 or via email at cmbuckley@harfordcountymd.gov

Sincerely,

CM Buckley

Christine Buckley, P.E.
Harford County
MS4 Program Manager

CMB/cmb

CC: S. Kearby
M. Dobson

1. *MDE would like to acknowledge that the absence of any required reductions for the agricultural sector in Swan Creek will make restoration in the watershed very difficult. MDE would like to discuss this issue with Harford County at an in-person meeting in the near future.*

   Harford County and MDE met on July 26, 2019

2. *MDE requests clarification on whether the County has attempted to coordinate with any of the other jurisdictions that have SW-WLAs in the Swan Creek watershed.*

   Harford County coordinates with the City of Havre de Grace and City of Aberdeen to discuss joint projects.

3. *MDE requests clarification on whether Harford County has coordinated with the Harford Soil Conservation District on any non-point source projects in the Swan Creek watershed (mentioned at the bottom of page 2-1) or only for property owner interactions.*

   Harford County has been activity working with the Harford Soil Conservation District to coordinate the implementation of a restoration project with SCD taking the lead on interactions with the property owners. SCD organized a joint meeting with one property owner to discuss a project which lead to a site visit and evaluation. The County is currently drafting a memorandum of understanding for review by SCD.

4. *Harford County should consider the Class II-P designated use mentioned on page 1-3 for purposes of coordination with other jurisdictions in the Swan Creek watershed. Drinking water designated uses should be given high priority for the purposes of restoration and planning.*

   The drinking water designation is for the City of Aberdeen's water supply. All projects completed within the Swan Creek Watershed would ultimately lower sedimentation into the water treatment plant. Harford County will continue to coordinate with the City of Aberdeen for potential joint projects.

5. *In Section 2.1, Harford County described how potential projects are prioritized and selected. MDE asks that the County provide a schematic illustrating this prioritization process, and explain if the process is quantifiable.*

   The process is not quantifiable and is based on best professional judgement. Prioritization was weighted most strongly based on SCD's past interactions with property owners.

6. *Figure 2-1 is excellent and MDE requests that the County compliment this figure with a prioritization schematic that contains a list of projects.*

   Attached is an updated Figure 2-1 which includes labels for each potential project along with a corresponding table. The table includes number of parcels and length of stream.

7. *If Harford County is comfortable doing so, it would be useful for the preservation of data to mark on Figure 2-1 generally where site access is difficult/problematic so all records of efforts to implement are maintained.*

   As mentioned in the report on page 2-3, this information was not included to protect property owner's privacy.

8. *MDE requests that the County clarify the reason only those sites mentioned in the sentence on page 2-3 will be addressed: "Only sites failing MBSS protocols will be pursued."*

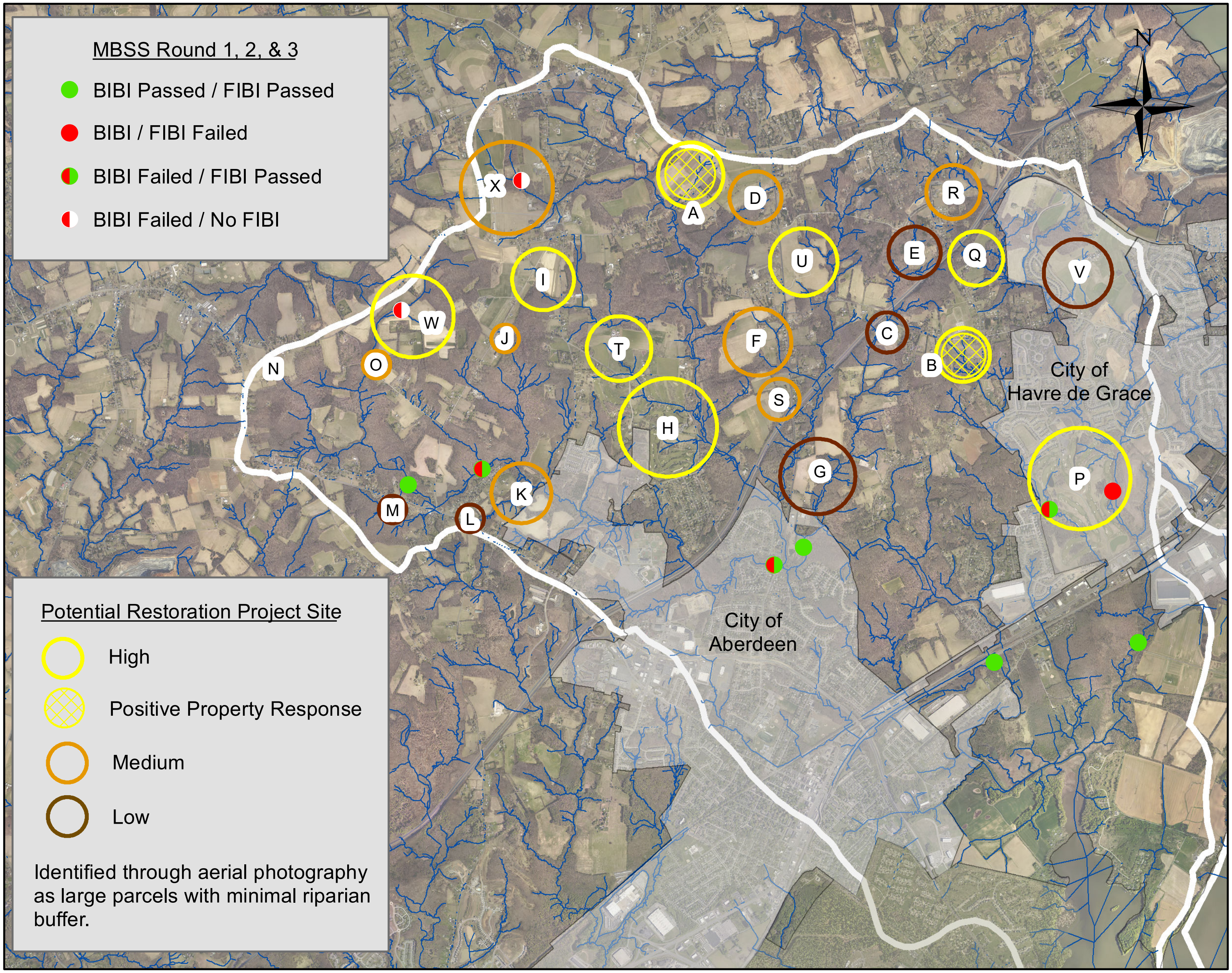
Harford County will evaluate the outcomes of biological and habitat assessments when determining project viability.

9. *In reference to page 2-3, MDE requests clarification on the reason projects "with a minimum stream length of 1,000 linear feet" are the only projects being considered. MDE recommends Harford County keep in mind that restoration is likely warranted throughout the watershed.*

Based on cost to benefit ratio and economies of scale, Harford County has chosen a minimum length of stream for restoration projects.

10. *MDE recommends that Harford County demonstrate that upstream jurisdictions and contributions to the stream restoration projects the County has decided to fund are being managed and stable prior to breaking ground on these projects to ensure proper return on investment in the restoration work and their longevity.*

While it is ideal to complete restoration projects from the headwaters to the confluence, logistically it is impractical when nearly all the property is privately owned and / or located within other jurisdictions.



Swan Creek Restoration Plan for Sediment

0 0.5 1 2 3 Miles

1 in = 1 miles

Printed 2/2020

Barry Glassman
County Executive

Swan Creek Potential Restoration Project Sites

Name	Rank	NoParcels	StrmLen
A	High	1	4,000
B	High	1	2,000
H	High	1	9,000
I	High	1	400
P	High	2	20,000
Q	High	1	2,000
T	High	1	2,000
U	High	1	3,000
W	High	1	4,000
C	Low	1	4,000
E	Low	2	3,000
G	Low	1	800
L	Low	1	400
M	Low	1	300
N	Low	1	200
V	Low	1	6,000
D	Medium	1	5,000
F	Medium	1	3,000
J	Medium	1	1,000
K	Medium	1	1,000
O	Medium	1	1,000
R	Medium	1	2,000
S	Medium	2	1,000
X	Medium	1	5,000

September 19, 2019

To: Harford County Watershed Protection and Restoration Office
From: Maryland Department of the Environment (MDE) – Integrated Water Planning Program (IWPP)
Subject: Approval of Harford County's Stormwater Wasteload Allocation (SW-WLA) Watershed Implementation Plan (WIP) for the Total Suspended Solids (TSS) impairment of Swan Creek

The Harford County SW-WLA implementation plan was initially submitted on September 29, 2017 and revised in the subsequent fiscal year 2018 municipal separate storm sewer system (MS4) annual report to address comments from MDE's IWPP. The revised plan is of sufficient quality to warrant MDE approval.

MDE's IWPP reviewed the plan for both its technical merits and watershed planning components. The comments the IWPP provided, both major and minor, asked for revisions to both small and large technical details of the modeling that the County conducted, which would affect potential implementation strategies and the tracking of pollutant load reductions in comparison to target reductions. The County has since made the technical fixes to the plan as requested by MDE's IWPP, or the County has responded to MDE's original comments providing an acceptable justification as to why revisions to the plan were not required.

Below are specific points that demonstrate why this plan is of sufficient quality to the IWPP:

- The County has provided reasonable end-dates for achieving the SW-WLA
- The County has provided detailed cost estimates for implementation
- The County used scientifically defensible modeling tools for estimating the watershed baseline load
- The County implementation plan incorporates elements of adaptive management, indicating that it will use water quality monitoring data to assess the effectiveness of implemented practices and adjust implementation strategies if data do not indicate positive trends
- The modeled baseline year is consistent with baseline conditions in the applicable total maximum daily load (TMDL)
- The County used SW-WLA reduction percentages rather than absolute loading targets from the TMDL in its implementation modeling to set loading targets in terms of its own modeling system
- The County outlined specific best management practices (BMPs) and the amounts of these control measures they plan to implement to meet the required loading reduction
- The County used scientifically defensible BMP reduction efficiencies in modeling the expected pollutant load reductions
- The County outlined a timeframe for achievement of the required pollutant load reduction

- The County discussed the mechanisms that it will employ for tracking progress towards the required load reductions

There is no information withheld from this plan at this point that should warrant it as being unacceptable per the IWPP's criteria for evaluation. However, the IWPP requests that comments provided to Harford County in the letter dated May 3, 2019 and subsequently discussed at the meeting between the IWPP and Harford County officials on Friday, July 26, 2019 be responded before January 26, 2019.

MDE IWPP Comments on Harford County Swan Creek TSS SW-WLA Implementation Plan

1. MDE would like to acknowledge that the absence of any required reductions for the agricultural sector in Swan Creek will make restoration in the watershed very difficult. MDE hopes to discuss this issue with Harford County at an in-person meeting in the near future.
2. Has Harford County attempted to coordinate with any of the other jurisdictions that have SW-WLAs in the Swan Creek watershed?
3. Has Harford County coordinated with the Soil Conservation District on any non-point source projects in the Swan Creek watershed (mentioned at the bottom of page 2-1) or only for property owner interactions?
4. Harford County should consider the Class II-P designated use mentioned on page 1-3 for purposes of coordination with other jurisdictions in the Swan Creek watershed. Drinking water designated uses should be given high priority for the purposes of restoration and planning.
5. In Section 2.1, Harford County describes how potential projects are prioritized and selected. MDE asks that the county provide a schematic illustrating this prioritization process, and explain if the process is quantifiable.
6. Figure 2-1 is excellent, can Harford County please compliment this figure with a prioritization schematic that contains a list of projects?
7. If Harford County is comfortable doing so, it would be useful for the preservation of data to mark on Figure 2-1 generally where site access is difficult/problematic so all records of efforts to implement are maintained
8. MDE requests that the County clarify the reason why only those sites mentioned in the sentence on page 2-3 will be addressed; "Only sites failing MBSS protocols will be pursued," will be pursued.
9. In reference to page 2-3, why are projects "with a minimum stream length of 1,000 linear feet" the only projects being considered? MDE recommends Harford County keep in mind that restoration is likely warranted throughout the watershed.
10. MDE recommends Harford County demonstrate that upstream jurisdictions and contributions tor the stream restoration projects they have decided to fund are being managed and stable prior to breaking ground on these projects to ensure proper return on investment in the restoration work and their longevity.

April 27, 2020

To: Harford County Watershed Protection and Restoration Office
From: Maryland Department of the Environment (MDE) – Integrated Water Planning Program (IWPP)
Subject: Conditional Approval of Harford County's Stormwater Wasteload Allocation (SW-WLA) Watershed Implementation Plan (WIP) for the Total Suspended Solids (TSS) impairment of Bynum Run

The Harford County SW-WLA implementation plan was initially submitted on June 29, 2016 and revised in the fiscal year (FY) 2019 municipal separate storm sewer system (MS4) annual report submitted on December 30, 2019 to address comments from MDE's IWPP.

MDE's IWPP reviewed the plan for both its technical merits and watershed planning components. The comments the IWPP provided, both major and minor, asked for revisions to both small and large technical details of the modeling that the County conducted, which would affect potential implementation strategies and the tracking of pollutant load reductions in comparison to target reductions. The County has since made the technical fixes to the plan as requested by MDE's IWPP, or the County has responded to MDE's original comments providing an acceptable justification as to why revisions to the plan were not required.

The County still needs to provide information related to:

- Reasonable end-dates for achieving the SW-WLA

MDE's IWPP requests a red-lined revision that incorporates the above to be submitted with the FY2020 annual report, due December 30, 2020. The plan is conditionally approved and upon resolution of the above mentioned, the plan will be granted full-approval. Below are specific points that demonstrate why this plan is otherwise of sufficient quality to the IWPP:

- The County has provided detailed cost estimates for implementation
- The County used scientifically defensible modeling tools for estimating the watershed baseline load
- The County implementation plan incorporates elements of adaptive management, indicating that it will use water quality monitoring data to assess the effectiveness of implemented practices and adjust implementation strategies if data do not indicate positive trends
- The modeled baseline year is consistent with baseline conditions in the applicable total maximum daily load (TMDL)
- The County used SW-WLA reduction percentages rather than absolute loading targets from the TMDL in its implementation modeling to set loading targets in terms of its own modeling system

- The County outlined specific best management practices (BMPs) and the amounts of these control measures it plans to implement to meet the required loading reduction
- The County used scientifically defensible BMP reduction efficiencies in modeling the expected pollutant load reductions
- The County outlined a timeframe for achievement of the required pollutant load reduction
- The County discussed the mechanisms that it will employ for tracking progress towards the required load reductions

Maryland
Department of
the Environment

Larry Hogan, Governor
Boyd K. Rutherford, Lt. Governor

Ben Grumbles, Secretary
Horacio Tablada, Deputy Secretary

April 27, 2020

To: Harford County Watershed Protection and Restoration Office
From: Maryland Department of the Environment (MDE) – Integrated Water Planning Program (IWPP)
Subject: Review of Harford County's Stormwater Wasteload Allocation (SW-WLA) Watershed Implementation Plan (WIP) for the Polychlorinated Biphenyl (PCB) impairment of Bush River

The Harford County SW-WLA implementation plan was initially submitted to MDE on August 2, 2017 and revised and submitted with the fiscal years 2018 and 2019 municipal separate storm sewer system (MS4) annual reports to address comments from MDE's IWPP.

MDE's IWPP reviewed the plan for both its technical merits and watershed planning components. The comments the IWPP provided, both major and minor, asked for revisions to both small and large technical details of the modeling that the County conducted, which would affect potential implementation strategies and the tracking of pollutant load reductions in comparison to target reductions. The County has since made the technical fixes to the plan as requested by MDE's IWPP, or the County has responded to MDE's original comments providing an acceptable justification as to why revisions to the plan were not required. The plan is a good starting point for watershed restoration efforts.

The plan is of sufficient quality for Harford County to continue forward with the outlined implementation strategies. However, MDE's IWPP does not approve the current submission of the plan because two major comments are unaddressed. The County must submit a revised plan within the next 6 months, no later than October 23, 2020, in order to receive approval that includes information related to:

- Comment #10 in the comments from MDE IWPP dated: May 3, 2019. This comment requests that the County record specifically what management issues might need to be addressed in the future. This comment is referring to iterative/adaptive management, which is a permit requirement. If the County needs examples for how it can address this comment or needs further clarification on the nature of the comment, please reach out to MDE IWPP for guidance.
- Comment #12 in the comments from MDE IWPP dated: May 3, 2019. The comment was not addressed as the plan still states that the gross load from the sediments is the major source of PCBs to the river. The comment requested that the County change the language. The information is incorrect and needs to be revised; the implications are that in-situ remediation would be the primary remediation technique, which is not a determination that has been made based on monitoring.

StateUniqueIdentifier	AgencyCode	StateAbbreviation	GeographyName	BmpShortname	LoadSourceGroup	Amount	Unit
CIP0012	nonfed	md	N24025WU0_3250_0001	urbstrmrest	streambedandbank	465	feet
CIP0013	nonfed	md	N24025WU1_3331_3330	urbstrmrest	streambedandbank	1680	feet
CIP0015	nonfed	md	N24025WU1_3330_0001	RR		0.47	acres
CIP0015	nonfed	md	N24025WU1_3330_0001	RR		0.071	acre-feet
CIP0015	nonfed	md	N24025WU1_3330_0001	RR		0.47	impervious acres
CIP0016	nonfed	md	N24025WU0_3250_0001	RR		0.39	acres
CIP0016	nonfed	md	N24025WU0_3250_0001	RR		0.033	acre-feet
CIP0016	nonfed	md	N24025WU0_3250_0001	RR		0.28	impervious acres
CIP0017	nonfed	md	N24025SL2_3060_0001	RR		0.68	acres
CIP0017	nonfed	md	N24025SL2_3060_0001	RR		0.059	acre-feet
CIP0017	nonfed	md	N24025SL2_3060_0001	RR		0.54	impervious acres
CIP0018	nonfed	md	N24025WU0_3250_0001	ST		36	acres
CIP0018	nonfed	md	N24025WU0_3250_0001	ST		0.970	acre-feet
CIP0018	nonfed	md	N24025WU0_3250_0001	ST		11.52	impervious acres
CIP0019	nonfed	md	N24025WU0_3540_0000	ST		30.8	acres
CIP0019	nonfed	md	N24025WU0_3540_0000	ST		2.250	acre-feet

CIP0019	nonfed	md	N24025WU0_3540_0000	ST		10	impervious acres
CIP0020	nonfed	md	N24025WU0_3540_0000	urbstrmrest	streambedandbank	1237	feet
CIP0022	nonfed	md	N24025WU1_3331_3330	ST		104.15	acres
CIP0022	nonfed	md	N24025WU1_3331_3330	ST		9.758	acre-feet
CIP0022	nonfed	md	N24025WU1_3331_3330	ST		35.7	impervious acres
CIP0024	nonfed	md	N24025WU1_3331_3330	ST		35.11	acres
CIP0024	nonfed	md	N24025WU1_3331_3330	ST		0.569	acre-feet
CIP0024	nonfed	md	N24025WU1_3331_3330	ST		6.97	impervious acres
CIP0080	nonfed	md	N24025WU1_3331_3330	ST		12.62	acres
CIP0080	nonfed	md	N24025WU1_3331_3330	ST		0.152	acre-feet
CIP0080	nonfed	md	N24025WU1_3331_3330	ST		3.79	impervious acres
CIP0025	nonfed	md	N24025WU1_3331_3330	ST		9.72	acres
CIP0025	nonfed	md	N24025WU1_3331_3330	ST		0.366	acre-feet
CIP0025	nonfed	md	N24025WU1_3331_3330	ST		3.49	impervious acres
CIP0026	nonfed	md	N24025WU1_3331_3330	ST		25.68	acres
CIP0026	nonfed	md	N24025WU1_3331_3330	ST		1.001	acre-feet
CIP0026	nonfed	md	N24025WU1_3331_3330	ST		23.56	impervious acres

CIP0027	nonfed	md	N24025WU1_3331_3330	urbstrmrest	streambedandbank	2431	feet
CIP0075	nonfed	md	N24025WU1_3331_3330	urbstrmrest	streambedandbank	1939	feet
CIP0076	nonfed	md	N24025WU1_3331_3330	ST		10.69	acres
CIP0076	nonfed	md	N24025WU1_3331_3330	ST		0.212	acre-feet
CIP0076	nonfed	md	N24025WU1_3331_3330	ST		3.74	impervious acres
CIP0077	nonfed	md	N24025WU1_3331_3330	ST		12.6	acres
CIP0077	nonfed	md	N24025WU1_3331_3330	ST		0.210	acre-feet
CIP0077	nonfed	md	N24025WU1_3331_3330	ST		4.2	impervious acres
CIP0078	nonfed	md	N24025WU1_3331_3330	ST		19.41	acres
CIP0078	nonfed	md	N24025WU1_3331_3330	ST		0.167	acre-feet
CIP0078	nonfed	md	N24025WU1_3331_3330	ST		7.42	impervious acres
CIP0079	nonfed	md	N24025WU1_3331_3330	ST		6.07	acres
CIP0079	nonfed	md	N24025WU1_3331_3330	ST		0.117	acre-feet
CIP0079	nonfed	md	N24025WU1_3331_3330	ST		2.3	impervious acres
CIP0029	nonfed	md	N24025WU0_3250_0001	urbstrmrest	streambedandbank	3084	feet
CIP0030	nonfed	md	N24025WU1_3331_3330	urbstrmrest	streambedandbank	725	feet
CIP0031	nonfed	md	N24025SL2_2910_3060	RR		1.25	acres

CIP0031	nonfed	md	N24025SL2_2910_3060	RR		0.088	acre-feet
CIP0031	nonfed	md	N24025SL2_2910_3060	RR		0.5	impervious acres
CIP0032	nonfed	md	N24025WU0_3540_0000	urbstrmrest	streambedandbank	1213	feet
	nonfed	md	N24025WU0_3251_0000	ST		0	acres
	nonfed	md	N24025WU0_3251_0000	ST		0.000	acre-feet
	nonfed	md	N24025WU0_3251_0000	ST		0	impervious acres
	nonfed	md	N24025WU0_3251_0000	ST		0	acres
	nonfed	md	N24025WU0_3251_0000	ST		0.000	acre-feet
	nonfed	md	N24025WU0_3251_0000	ST		0	impervious acres
CIP0033	nonfed	md	N24025WU0_3251_0000	urbstrmrest	streambedandbank	2028	feet
CIP0108	nonfed	md	N24025WU0_3251_0000	ST		10.25	acres
CIP0108	nonfed	md	N24025WU0_3251_0000	ST		0.607	acre-feet
CIP0108	nonfed	md	N24025WU0_3251_0000	ST		2.32	impervious acres
CIP0109	nonfed	md	N24025WU0_3251_0000	ST		0	acres
CIP0109	nonfed	md	N24025WU0_3251_0000	ST		0.000	acre-feet
CIP0109	nonfed	md	N24025WU0_3251_0000	ST		0	impervious acres
CIP0110	nonfed	md	N24025WU0_3251_0000	ST		44.75	acres

CIP0110	nonfed	md	N24025WU0_3251_0000	ST		0.550	acre-feet
CIP0110	nonfed	md	N24025WU0_3251_0000	ST		13.19	impervious acres
CIP0035	nonfed	md	N24025WU1_3331_3330	ST		31.15	acres
CIP0035	nonfed	md	N24025WU1_3331_3330	ST		0.765	acre-feet
CIP0035	nonfed	md	N24025WU1_3331_3330	ST		8.74	impervious acres
CIP0100	nonfed	md	N24025WU1_3331_3330	urbstrmrest	streambedandbank	1055	feet
CIP0101	nonfed	md	N24025WU1_3331_3330				
CIP0036	nonfed	md	N24025WU0_3540_0000	urbstrmrest	streambedandbank	2090	feet
CIP0097	nonfed	md	N24025WU0_3540_0000	RR		28.4	acres
CIP0097	nonfed	md	N24025WU0_3540_0000	RR		0.025	acre-feet
CIP0097	nonfed	md	N24025WU0_3540_0000	RR		1	impervious acres
	nonfed	md	N24025WU1_3331_3330	ST		0	acres
	nonfed	md	N24025WU1_3331_3330	ST		0.000	acre-feet
	nonfed	md	N24025WU1_3331_3330	ST		0	impervious acres
CIP0039	nonfed	md	N24025WU1_3331_3330	ST		0	acres
CIP0039	nonfed	md	N24025WU1_3331_3330	ST		0.000	acre-feet
CIP0039	nonfed	md	N24025WU1_3331_3330	ST		0	impervious acres

CIP0111	nonfed	md	N24025WU1_3331_3330	ST		13.88	acres
CIP0111	nonfed	md	N24025WU1_3331_3330	ST		0.513	acre-feet
CIP0111	nonfed	md	N24025WU1_3331_3330	ST		7	impervious acres
CIP0112	nonfed	md	N24025WU1_3331_3330	urbstrmrest	streambedandbank	2512	feet
CIP0113	nonfed	md	N24025WU1_3331_3330	ST		8.33	acres
CIP0113	nonfed	md	N24025WU1_3331_3330	ST		0.089	acre-feet
CIP0113	nonfed	md	N24025WU1_3331_3330	ST		0.97	impervious acres
CIP0114	nonfed	md	N24025WU1_3331_3330	RR		5.77	acres
CIP0114	nonfed	md	N24025WU1_3331_3330	RR		0.051	acre-feet
CIP0114	nonfed	md	N24025WU1_3331_3330	RR		1.65	impervious acres
CIP0115	nonfed	md	N24025WU1_3331_3330	ST		3.5	acres
CIP0115	nonfed	md	N24025WU1_3331_3330	ST		0.036	acre-feet
CIP0115	nonfed	md	N24025WU1_3331_3330	ST		2.28	impervious acres
CIP0042	nonfed	md	N24025WU1_3330_0001	impsurred		2.82	acres
CIP0046	nonfed	md	N24025WU0_3254_0000	RR		0.22	acres
CIP0046	nonfed	md	N24025WU0_3254_0000	RR		0.014	acre-feet
CIP0046	nonfed	md	N24025WU0_3254_0000	RR		0.13	impervious acres

CIP0102	nonfed	md	N24025WU0_3254_0000	RR		0.1	acres
CIP0102	nonfed	md	N24025WU0_3254_0000	RR		0.008	acre-feet
CIP0102	nonfed	md	N24025WU0_3254_0000	RR		0.1	impervious acres
CIP0103	nonfed	md	N24025WU0_3254_0000	RR		0.27	acres
CIP0103	nonfed	md	N24025WU0_3254_0000	RR		0.025	acre-feet
CIP0103	nonfed	md	N24025WU0_3254_0000	RR		0.13	impervious acres
CIP0048	nonfed	md	N24025WU1_3331_3330	urbanforplant		0.57	acres
CIP0049	nonfed	md	N24025SL2_3060_0001	urbanforplant		0.84	acres
CIP0050	nonfed	md	N24025SL2_3060_0001	urbanforplant		0.31	acres
CIP0051	nonfed	md	N24025SL2_3060_0001	urbanforplant		0.58	acres
CIP0052	nonfed	md	N24025SL2_3060_0001	urbanforplant		1.8	acres
CIP0096	nonfed	md	N24025SL2_2910_3060	urbanforplant		0.55	acres
CIP0081	nonfed	md	N24025WU0_3253_0000	urbanforplant		0.55	acres
CIP0082	nonfed	md	N24025WU0_3253_0000	urbanforplant		0.57	acres
CIP0083	nonfed	md	N24025WU0_3253_0000	urbanforplant		3.03	acres
CIP0084	nonfed	md	N24025WU0_3253_0000	urbanforplant		0.35	acres
CIP0053	nonfed	md	N24025WU0_3161_0000	urbanforplant		0.7	acres

CIP0054	nonfed	md	N24025WU1_3331_3330	urbanforplant		2.33	acres
CIP0055	nonfed	md	N24025WU1_3331_3330	urbanforplant		0.43	acres
CIP0085	nonfed	md	N24025WU0_3250_0001	urbanforplant		3.16	acres
CIP0056	nonfed	md	N24025WU0_3540_0000	urbanforplant		0.6	acres
CIP0057	nonfed	md	N24025WU0_3250_0001	urbanforplant		2.11	acres
CIP0058	nonfed	md	N24025SL0_2721_2720	urbanforplant		0.4	acres
CIP0059	nonfed	md	N24025WU0_3253_0000	urbanforplant		3.24	acres
CIP0094	nonfed	md	N24025WU0_3253_0000	urbanforplant		1.54	acres
CIP0060	nonfed	md	N24025WU0_3253_0000	urbanforplant		1.96	acres
CIP0095	nonfed	md	N24025WU0_3253_0000	urbanforplant		0.62	acres
CIP0061	nonfed	md	N24025SL2_2910_3060	urbanforplant		0.47	acres
CIP0062	nonfed	md	N24025SL0_2721_2720	urbanforplant		1.33	acres
CIP0063	nonfed	md	N24025WU0_3161_0000	urbanforplant		1.65	acres
CIP0068	nonfed	md	N24025WU1_3240_3331	impsurred		0.07	acres
CIP0070	nonfed	md	N24025WU1_3330_0001	RR		8.3	acres
CIP0070	nonfed	md	N24025WU1_3330_0001	RR		0.403	acre-feet
CIP0070	nonfed	md	N24025WU1_3330_0001	RR		3.1	impervious acres

CIP0098	nonfed	md	N24025WU1_3330_0001	urbanforplant		1.36	acres
CIP0099	nonfed	md	N24025WU1_3330_0001	RR		0.89	acres
CIP0099	nonfed	md	N24025WU1_3330_0001	RR		0.019	acre-feet
CIP0099	nonfed	md	N24025WU1_3330_0001	RR		0.16	impervious acres
CIP0073	nonfed	md	N24025SL2_3060_0001	RR		9.71	acres
CIP0073	nonfed	md	N24025SL2_3060_0001	RR		0.063	acre-feet
CIP0073	nonfed	md	N24025SL2_3060_0001	RR		3.97	impervious acres
CIP0074	nonfed	md	N24025WU1_3240_3331	urbstrmrest	streambedandbank	3675	feet
CIP0105	nonfed	md	N24025WU1_3240_3331	urbstrmrest	streambedandbank	3258	feet
CIP0106	nonfed	md	N24025WU1_3240_3331	urbanforplant		3.01	acres
CIP0107	nonfed	md	N24025WU1_3331_3330	urbstrmrest	streambedandbank	286	feet
CIP0104	nonfed	md	N24025WU1_3331_3330	RR		7.04	acres
CIP0104	nonfed	md	N24025WU1_3331_3330	RR		0.131	acre-feet
CIP0104	nonfed	md	N24025WU1_3331_3330	RR		2.91	impervious acres
CIP0086	nonfed	md	N24025WU1_3240_3331	urbanforplant		0.6	acres
CIP0087	nonfed	md	N24025WU1_3240_3331	urbanforplant		0.26	acres
CIP0088	nonfed	md	N24025WU1_3240_3331	urbanforplant		0.65	acres

CIP0089	nonfed	md	N24025WU0_3540_0000	urbanforplant		0.22	acres
CIP0090	nonfed	md	N24025WU0_3540_0000	urbanforplant		1.02	acres
CIP0091	nonfed	md	N24025WU1_3330_0001	urbanforplant		1.3	acres
CIP0092	nonfed	md	N24025SL2_3060_0001	urbanforplant		0.68	acres
CIP0093	nonfed	md	N24025SL2_3060_0001	urbanforplant		0.04	acres
CIP0116	nonfed	md	N24025WU1_3331_3330	RR		0.48	acres
CIP0116	nonfed	md	N24025WU1_3331_3330	RR		0.050	acre-feet
CIP0116	nonfed	md	N24025WU1_3331_3330	RR		0.44	impervious acres
CIP0117	nonfed	md	N24025WU0_3540_0000	urbantreeplant		0.34	acres

Sector	BMPFullName	BMPShortName	LoadSourceGroup	LoadSourceGroupFullName
Developed	Forest Planting	urbanforplant	ms4turfgrass	MS4 Turf Grass
Developed	Stormwater Performance Standard-Runoff Reduction	rr	ms4	MS4 Developed
Developed	Stormwater Performance Standard-Runoff Reduction	rr	ms4buildingsandother	MS4 Buildings and Other
Developed	Stormwater Performance Standard-Runoff Reduction	rr	ms4css	MS4 and CSS Developed
Developed	Stormwater Performance Standard-Runoff Reduction	rr	ms4cssnonregulated	Developed
Developed	Stormwater Performance Standard-Runoff Reduction	rr	ms4nonregulated	MS4 Nonregulated Developed
Developed	Stormwater Performance Standard-Runoff Reduction	rr	ms4roads	MS4 Roads
Developed	Stormwater Performance Standard-Runoff Reduction	rr	ms4treecanopyoverimpervious	MS4 Tree Canopy over Impervious
Developed	Stormwater Performance Standard-Runoff Reduction	rr	ms4treecanopyoverturfgrass	MS4 Tree Canopy over Turf Grass
Developed	Stormwater Performance Standard-Runoff Reduction	rr	ms4turfgrass	MS4 Turf Grass
Developed	Stormwater Performance Standard-Stormwater Treatment	st	ms4	MS4 Developed
Developed	Stormwater Performance Standard-Stormwater Treatment	st	ms4buildingsandother	MS4 Buildings and Other
Developed	Stormwater Performance Standard-Stormwater Treatment	st	ms4css	MS4 and CSS Developed
Developed	Stormwater Performance Standard-Stormwater Treatment	st	ms4cssnonregulated	Developed
Developed	Stormwater Performance Standard-Stormwater Treatment	st	ms4nonregulated	MS4 Nonregulated Developed
Developed	Stormwater Performance Standard-Stormwater Treatment	st	ms4roads	MS4 Roads

Developed	Stormwater Performance Standard-Stormwater Treatment	st	ms4treecanopyoverimpervious	MS4 Tree Canopy over Impervious
Developed	Stormwater Performance Standard-Stormwater Treatment	st	ms4treecanopyoverturfgrass	MS4 Tree Canopy over Turf Grass
Developed	Stormwater Performance Standard-Stormwater Treatment	st	ms4turfgrass	MS4 Turf Grass
Developed	Tree Planting - Canopy	urbantreeplant	ms4buildingsandother	MS4 Buildings and Other
Developed	Tree Planting - Canopy	urbantreeplant	ms4roads	MS4 Roads
Developed	Tree Planting - Canopy	urbantreeplant	ms4turfgrass	MS4 Turf Grass

Note:
Existing BMPs for RR and ST use a single Load Source Group of ms4cssnongregulated. ***Should that Load Source Group also be used for restoration projects?***

StateUniqueIdentifier	AgencyCode	StateAbbreviation	GeographyName	BmpShortname	LoadSourceGroup	Amount	Unit
	nonfed	md	N24025WU0_3540_0000	urbstrmrest	streambedandbank	2000	feet
CIP0014	nonfed	md	N24025WU1_3240_3331	urbstrmrest	streambedandbank	2000	feet
CIP0021	nonfed	md	N24025WU0_3250_0001	urbstrmrest	streambedandbank	3000	feet
	nonfed	md	N24025WU0_3253_0000	RR			acres
	nonfed	md	N24025WU0_3253_0000	RR			acre-feet
	nonfed	md	N24025WU0_3253_0000	RR			impervious acres
CIP0034	nonfed	md	N24025WU0_3253_0000	RR			acres
CIP0034	nonfed	md	N24025WU0_3253_0000	RR			acre-feet
CIP0034	nonfed	md	N24025WU0_3253_0000	RR			impervious acres
CIP0034	nonfed	md	N24025WU0_3253_0000	urbstrmrest	streambedandbank	3000	feet
	nonfed	md	N24025WU0_3540_0000	urbstrmrest	streambedandbank	2000	feet
	nonfed	md	N24025WU0_3540_0000	ST			acres
	nonfed	md	N24025WU0_3540_0000	ST			acre-feet
	nonfed	md	N24025WU0_3540_0000	ST			impervious acres
	nonfed	md	N24025WU0_3540_0000	urbstrmrest	streambedandbank	100	feet
CIP0043	nonfed	md	N24025WU0_3253_0000	urbstrmrest	streambedandbank	1940	feet

	nonfed	md	N24025WU1_3240_3331	RR			acres
	nonfed	md	N24025WU1_3240_3331	RR			acre-feet
	nonfed	md	N24025WU1_3240_3331	RR			impervious acres
	nonfed	md	N24025WU0_3250_0001	urbstrmrest	streambedandbank	4000	feet
	nonfed	md	N24025WU0_3250_0001	urbstrmrest	streambedandbank	2000	feet
	nonfed	md	N24025WU1_3240_3331	urbstrmrest	streambedandbank	2000	feet
	nonfed	md	N24025WU1_3240_3331	urbstrmrest	streambedandbank	4000	feet
	nonfed	md	N24025WU1_3240_3331	RR			acres
	nonfed	md	N24025WU1_3240_3331	RR			acre-feet
	nonfed	md	N24025WU1_3240_3331	RR			impervious acres
	nonfed	md	N24025WU1_3240_3331	RR			acres
	nonfed	md	N24025WU1_3240_3331	RR			acre-feet
	nonfed	md	N24025WU1_3240_3331	RR			impervious acres
	nonfed	md	N24025WU0_3250_0001	RR			acres
	nonfed	md	N24025WU0_3250_0001	RR			acre-feet
	nonfed	md	N24025WU0_3250_0001	RR			impervious acres
	nonfed	md	N24025WU0_3250_0001	RR			acres

	nonfed	md	N24025WU0_3250_0001	RR			acre-feet
	nonfed	md	N24025WU0_3250_0001	RR			impervious acres
	nonfed	md	N24025WU0_3250_0001	ST			acres
	nonfed	md	N24025WU0_3250_0001	ST			acre-feet
	nonfed	md	N24025WU0_3250_0001	ST			impervious acres

Foster Branch

Year 5 - 2020 Monitoring Results

December | 2020

Prepared For

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Background and Objectives

Harford County Department of Public Works (DPW) commissioned a watershed action plan for the Foster Branch watershed. The Foster Branch Small Watershed Action Plan (BayLand 2013) was completed in January of 2013. The plan outlines restoration projects and storm-water retrofits throughout this approximately 1,400 acre watershed. In anticipation of the permit conditions which may be placed on these restoration projects by Maryland Department of the Environment (MDE) and the U.S. Army Corps of Engineers (USACE), a monitoring plan was developed for the Foster Branch watershed. KCI Technologies, Inc. (KCI) developed the *Foster Branch Monitoring Plan* (Harford County 2016) with sites located generally upstream and downstream of proposed or constructed restoration projects.

KCI Technologies, Inc. completed the fifth year of chemical, physical, and biological stream sampling in spring and summer of 2020 at the five stream sites described in the plan. This technical memorandum describes the methods and results of the five years of sampling conducted at the Foster Branch sites.

The primary goal of this effort is to characterize baseline stream conditions (biological, physical habitat, and *in situ* chemical) prior to additional restoration project/BMP implementation. A secondary goal is to conduct monitoring in Foster Branch that can be used to document ecological uplift and habitat improvement as projects are completed within this watershed.

1 Methods

The monitoring effort includes chemical (*in situ* water quality), physical (habitat assessment), and biological (benthic macroinvertebrate, fish, herpetofauna, freshwater mussels, and crayfish) assessments conducted at each of the selected sites. The sampling methods used are consistent with Maryland Department of Natural Resources' (DNR) Maryland Biological Stream Survey (MBSS). The methods have been developed locally and are calibrated specifically to Maryland's ecophysiographic regions and stream types.

1.1 Sampling Sites

Five sampling sites were selected within the Foster Branch watershed (Figure 1) to characterize baseline stream conditions and to assess the effect of planned restoration on the ecological health of the watershed. A brief description of sites follows, for more detailed information about each site see the *Foster Branch Monitoring Plan* (Harford County 2016).

1.1.1 Fost-1

Site Fost-1 is located close to the head-of-tide near the downstream most point in the Foster Branch watershed. This site is co-located with the USGS stream gage on Foster Branch (01585075). A stream restoration was previously completed by Harford County at this location and Fost-1 is located wholly within the restored reach. The land use upstream of Fost-1 is mostly urban (65.7%) with most of the remaining portion in forest (31.3%). This site will integrate the effects of all future restoration projects in the watershed.

1.1.2 Fost-2

Fost-2 is located on east branch of Foster Branch a short distance upstream of Trimble Rd and the confluence with the west branch. This site is located within a future planned stream restoration project. This site is the most urban of the Foster Branch sites, with 77.4% of the upstream watershed in urban and 22.1% in forest categories. This site will measure ecological response to all restoration projects on the east branch as they are implemented.

1.1.3 Fost-3

The site Fost-3 is located on the west branch of Foster Branch in a similar relative position as Fost-2, a short distance upstream of Trimble Rd and the confluence with the east branch. The west branch is the larger of the two branches of Foster Branch. This site is located a short distance downstream of both a planned stream restoration project and a planned sediment removal project. This site will integrate and assess the ecological benefit of all implemented restoration projects in the west branch.

1.1.4 Fost-4

This site is located on an unnamed tributary to the west branch, primarily draining forested (65.5%) land. This site has the smallest amount of urbanization (19.7% urban, approximately 2% impervious)) in its upstream drainage. Two large stream restoration projects are planned for the headwaters of this unnamed tributary. This site will measure ecological lift possibly attributable to stream restoration in a minimally developed subwatershed. Due to this site's small drainage area (approx. 100 acres) a Maryland-specific species-area curve suggests that very few, if any, fish species are expected to be observed; therefore fish community may not be a useful indicator of stream condition. Since fish community will not be a useful indicator, this site will only be sampled for fish in Year 1 and Year 4 of sampling.

1.1.5 Fost-5

This site is located on an unnamed tributary to the west branch, primarily draining urban (55.2%) land. This site is much more urban than Fost-4, with approximately 29% of the upstream area in impervious land cover. This site is downstream of two planned stream restoration projects and one new stormwater BMP. This site will assess the ecological benefit of planned restoration in a heavily urbanized subwatershed. Similarly to Fost-4, this site is of small drainage area and will only be sampled for fish in Year 1 and Year 4

1.2 Water Quality Sampling

Water quality conditions were measured *in situ* during the summer sampling visits at all Foster Branch sites. Currently the MBSS does not measure *in situ* water quality at sites, but did so in the past. *In situ* water quality methods used were consistent with those in DNR, 2010. Field measured parameters include temperature, dissolved oxygen, pH, specific conductance, and turbidity. Measurements at each site were made at the upstream end of the 75-meter long site. *In situ* measurements were made before any sampling activities started to avoid sampling water disturbed by other activities. Most *in situ* parameters (i.e., temperature, pH, specific conductivity, and dissolved oxygen) were measured using a multiparameter sonde (YSI Professional Plus), while turbidity was measured with a Hach 2100 Turbidimeter. Water quality meters are regularly inspected and maintained and were calibrated immediately prior to sampling to ensure proper usage and accuracy of the readings.

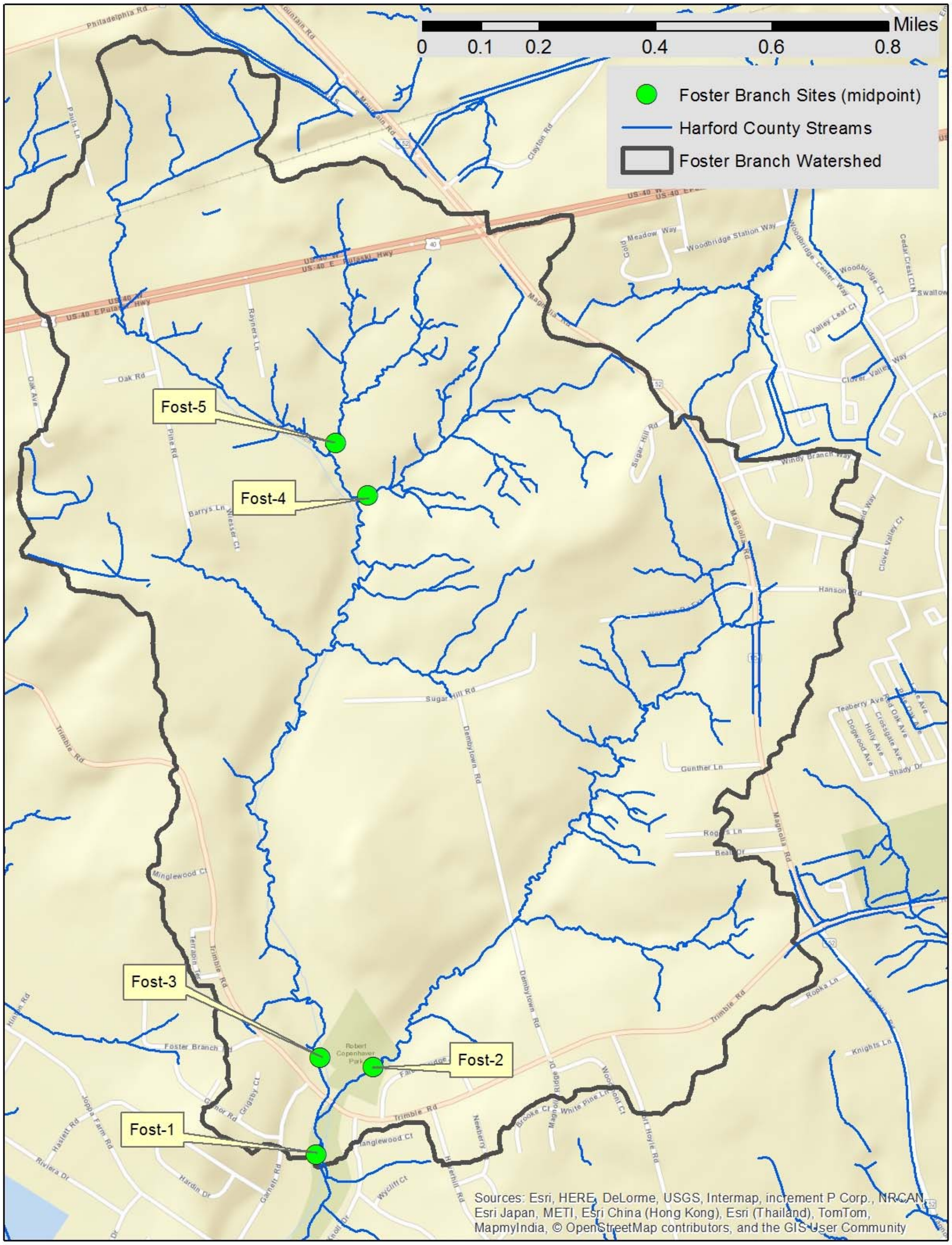

Figure 1 – Location of Sampling Sites

1.3 Physical Habitat Assessment

Each stream site was characterized based on visual observations of physical characteristics and various habitat parameters (Stranko et al., 2019). The Maryland Biological Stream Survey's (MBSS) Physical Habitat Index (PHI; Paul et al., 2002) was used to assess the physical habitat at the site.

To reduce individual sampler bias, assessments were completed as a team with discussion and agreement of the scoring for each parameter. In addition to the visual habitat assessments, photographs were taken from three locations within each sampling reach (downstream end, midpoint, and upstream end) facing in the upstream and downstream direction, for a total of six (6) photographs per site.

The PHI incorporates the results of a series of habitat parameters selected for Coastal Plain, Piedmont and Highlands regions. While all parameters are rated during the field assessment, the Coastal Plain parameters were used to develop the PHI score for these sites because the Foster Branch watershed is located in Maryland's coastal plain ecophysiographic region. In developing the PHI, MBSS identified eight parameters that have the most discriminatory power for the coastal plain streams. These parameters are used in calculating the PHI (Table 1). Several of the parameters have been found to be drainage area dependent and are scaled accordingly. The drainage area to each site was calculated in GIS using the GPS-collected location of each site, streams and 2-foot contour data from Harford County.

Table 1 – PHI Coastal Plain Parameters

Coastal Plain Stream Parameters	
Instream Habitat	Epibenthic Substrate
Bank Stability	Percent Shading
Remoteness	Number Woody Debris/Root wads

Each habitat parameter is given an assessment score ranging from 0-20, with the exception of shading (percentage 0-100%) and woody debris and root wads (total count). A prepared score and scaled score (0-100) are then calculated. The average of these scores yields the final PHI score. The final scores are then ranked according to the ranges shown in Table 2 and assigned corresponding narrative ratings, which allows for a score that can be compared to habitat assessments performed statewide.

Table 2 – PHI Score and Ratings

PHI Score	Narrative Rating
81.0 – 100.0	Minimally Degraded
66.0 – 80.9	Partially Degraded
51.0 – 65.9	Degraded
0.0 – 50.9	Severely Degraded

1.4 Benthic Macroinvertebrate Sampling

Benthic macroinvertebrate collection strictly followed MBSS procedures (Stranko et al., 2019). Sampling occurred during the Spring Index Period (March 1 – April 30), samples were collected from all five Foster Branch sites on March 5, 2020. The monitoring sites consist of a 75-meter reach and benthic macroinvertebrate sampling is conducted once per year. The sampling methods utilize semi-quantitative field collections of the benthic macroinvertebrate community. The multi-habitat D-frame net approach is used to sample a range of the most productive habitat types present within the reach. Best available habitats include riffles, stable woody debris, root wads, root mats, leaf packs, aquatic macrophytes, and undercut banks. In this sampling approach, a total of twenty jabs (each approximately one square foot) are distributed proportionally among all best available habitats within the stream site and combined into a single composite sample and preserved in 95 percent ethanol. The composite sample contains material collected from approximately 20 square feet of habitat.

MBSS specifies that a minimum of 5% (1 in 20) of sites are selected for a duplicate sample (Stranko et al., 2019). Because the total number of samples in this project (5) is well below 20, Foster Branch samples were pooled with other County monitoring project samples from Plumtree Run (5) and Wheel Creek (4) to meet the field sampling QC objective (1 in 14, or 7.14%). The randomly selected QC site for 2020 was taken at a site in the Plumtree Run watershed, Plum-2.

1.4.1 Benthic Macroinvertebrate Sample Processing and Laboratory Identification

Benthic macroinvertebrate samples were processed and subsampled according to methods described in the MBSS Laboratory Methods for Benthic Macroinvertebrate Processing and Taxonomy (Boward and Friedman 2019). Subsampling was conducted to standardize the sample size and reduce variation caused by samples of different size. In this method, the sample was spread evenly across a numbered, gridded tray (100 total grids), and a grid was picked at random and picked clean of organisms. If the organism count was 100 or more, then the subsampling was complete. If the organism count was less than 100, then another grid was selected at random and picked clean of organisms. This repeated until the organism count reached 100 to 120 organisms. The 100 (plus 20 percent) organism target is used to allow for specimens that are missing parts or are not mature enough for proper identification, are terrestrial, or meiofauna. Identification of the subsampled specimens was conducted by Cole Ecological, Inc. Taxa were identified to the genus level for most organisms. Groups including Oligochaeta and Nematomorpha were identified to the family level while Nematomorpha was left at phylum. Individuals of early instars or those that were damaged were identified to the lowest possible level, which could be phylum or order, but in most cases was family. Chironomidae could be further subsampled depending on the number of individuals in the sample and the numbers in each subfamily or tribe. Most taxa were identified using a stereoscope. Temporary slide mounts viewed with a compound microscope were used to identify Oligochaeta to family and for Chironomid sorting to subfamily and tribe. Permanent slide mounts were then used for Chironomid genus level identification. Results were logged on a bench sheet and entered into a spreadsheet for analysis.

1.4.2 Benthic Macroinvertebrate Data Analysis

Benthic macroinvertebrate data were analyzed by KCI using methods developed by MBSS as outlined in the *New Biological Indicators to Better Assess the Condition of Maryland Streams* (Southerland et al. 2005). The Benthic Index of Biotic Integrity (BIBI) approach involves statistical analysis using metrics that have a predictable response to water quality and/or habitat impairment. The metrics selected fall into five major groups including taxa richness, composition measures, tolerance to perturbation, trophic classification, and habit measures. Raw values from each metric were given a score of 1, 3 or 5 based on ranges of values developed for each metric. The results were combined into a scaled IBI score from 1.0 to 5.0, and a corresponding narrative biological condition rating was applied.

Three sets of metric calculations have been developed for Maryland streams based on broad eco-physiographic regions. These include the Coastal Plain, Piedmont and combined Highlands. The study area is located in the Coastal Plain region therefore the following metrics (Table 3) and IBI scoring (Table 4) were used for the analysis.

Table 3 – Benthic Macroinvertebrate Metric Scoring for the Coastal Plain BIBI

Metric	Score		
	5	3	1
Total Number of Taxa	≥ 22	14 – 21	< 14
Number of EPT Taxa	≥ 5	2 – 4	< 2
Number of Ephemeroptera Taxa	≥ 2	1 – 1	< 1
% Intolerant to Urban	≥ 28	10 - 27	< 10
% Ephemeroptera	≥ 11	0.8 – 10.9	< 0.8
Number of Scraper Taxa	≥ 2	1 - 1	< 1
% Climbers	≥ 8	0.9 – 7.9	< 0.9

*Adjusted for catchment size

Table 4 – BIBI Condition Ratings

IBI Score	Narrative Rating
4.00 – 5.00	Good
3.00 – 3.99	Fair
2.00 – 2.99	Poor
1.00 – 1.99	Very Poor

1.5 Fish Sampling

The fish community at two Foster Branch sites (Fost-1 and Fost-2) was sampled during the Summer Index Period, June 1 through September 30, according to methods described in *Maryland Biological Stream Survey: Round Four Field Sampling Manual* (Stranko et al., 2019). The Fost-3 site was not sampled during summer of 2020 due to unsampleable conditions. Beaver activity a short distance downstream of Fost-3 created beaver pond conditions throughout the downstream half of the site. Multiple visits were made to the site to assess sampleability, with the final visit taking place the week of September 28th. In general, the approach uses two-pass electrofishing of the entire 75-meter study reach. Block nets were placed at the upstream and downstream ends of the reach, as well as at tributaries or outfall channels, to obstruct fish movement into or out of the study reach. Two passes were completed along the reach to ensure the segment was adequately sampled. The time in seconds for each pass was recorded and the level of effort for each pass was similar. Captured fish were identified to species and enumerated following MBSS protocols (Stranko et al., 2019). A total fish biomass for each electrofishing pass was measured. Unusual anomalies such as fin erosion, tumors etc., were recorded. Photographic vouchers were taken in lieu of voucher specimens.

1.5.1 Fish Data Analysis

Fish data for Foster Branch sites were analyzed using methods developed by MBSS as outlined in the *New Biological Indicators to Better Assess the Condition of Maryland Streams* (DNR, 2005). The IBI approach involves statistical analysis using metrics that have a predictable response to water quality and/or habitat impairment. Raw values from each metric were assigned a score of 1, 3 or 5 based on ranges of values developed for each metric. The results were combined into a scaled FIBI score, ranging from 1.0 to 5.0, and a corresponding narrative rating of 'Good', 'Fair', 'Poor' or 'Very Poor' was applied, again in accordance with standard practice.

Four sets of FIBI metric calculations have been developed for Maryland streams based on DNR, 2005. These include the Coastal Plain, Eastern Piedmont, and warmwater and coldwater Highlands. Foster

Branch is located in the Coastal Plain region, therefore, the following metrics listed in Table 5 were used for the FIBI scoring (Table 6) and analysis.

Table 5 – Fish Metric Scoring for the Coastal Plain FIBI

Metric	Score		
	5	3	1
Abundance per square meter	≥ 0.72	0.45 – 0.71	< 0.45
Number of Benthic species *	≥ 0.22	0.01 – 0.21	0
% Tolerant	≤ 68	69 – 97	> 97
% Generalist, Omnivores, Invertivores	≤ 92	93 - 99	100
% Round-bodied Suckers	≥ 2	1	0
% Abundance of Dominant Taxa	≤ 40	41 - 69	< > 69

*Adjusted for catchment size

Table 6 – FIBI Condition Ratings

IBI Score	Narrative Rating
4.00 – 5.00	Good
3.00 – 3.99	Fair
2.00 – 2.99	Poor
1.00 – 1.99	Very Poor

1.6 Herpetofauna Survey

Herpetofauna (i.e., reptiles and amphibians) were surveyed at each of the five Foster Branch sites using methods following MBSS protocols (Stranko et al., 2019). All collected individuals were identified to species level and released. Photographic vouchers were collected if a specimen could not be positively identified in the field.

Herpetofauna data collection occurs primarily to assist MBSS with supplementing their inventory of biodiversity in Maryland's streams. Currently, MBSS has not developed any indexes of biotic integrity for herpetofauna, and therefore, they were not used to evaluate the biological integrity of sampling sites throughout this study. Rather, the data are provided to help document existing conditions.

1.7 Freshwater Mussel Survey

A survey of freshwater mussels was conducted at each site using MBSS protocols (Stranko et al., 2019). A search for freshwater mussels was conducted at each site. Any live individuals encountered were identified, photographed, and then returned back to the stream as closely as possible to where they were collected. Any dead shells were retained as voucher specimens.

1.8 Crayfish Survey

Crayfish were surveyed for at each sampling site using MBSS protocols (Stranko et al., 2019). All crayfish observed while electrofishing were captured and retained until the end of each electrofishing pass. Captured crayfish were identified to species and counted before release back into the stream outside of the 75-meter sampling reach. Any crayfish encountered outside of the electrofishing effort were identified and noted on the datasheet as an incidental observation. Any crayfish burrows observed in and around the sampling site were excavated and an attempt made to capture the burrowing crayfish.

1.9 Invasive Plant Survey

A survey of invasive plants was performed at each sampling site during the Summer Index Period following MBSS protocols (Stranko et al., 2019). The common name and relative abundance of invasive plants (i.e., present or extensive) within view of the study reach and within the 5-meter riparian vegetative zone parallel the stream channel were recorded.

Invasive plant data collection occurs to assist MBSS with supplementing their inventory of biodiversity. The data are provided to help document existing conditions at each site.

1.10 Quality Assurance and Quality Control

All work was conducted with thorough quality assurance and quality control. Biological assessment methods have been designed to be consistent and comparable with the methods used by MBSS (Stranko et al., 2019). Field crews receive yearly training in MBSS protocols and certification by DNR to perform benthic macroinvertebrate and fish sampling procedures. All field forms are checked and signed by the Crew Leader before leaving the site. Digital data entry is also checked for accuracy. Field equipment are checked regularly and calibrated as necessary prior to use. Calculation of metric scores and IBIs are completed using KCI's controlled and verified spreadsheet and each site undergoes a documented quality control check.

2 Results and Discussion

Biological monitoring and water quality sampling were conducted to assess the conditions in the Foster Branch watershed. Presented below are the summary results for each monitoring component.

2.1 Water Quality

Water quality measurements were collected during the Summer Index Period sampling visit at the three Foster Branch sites. Table 7 presents the results of the *in situ* water quality measurements for Year 1 (summer 2015), Year 2 (summer 2016), Year 3 (summer 2017), Year 4 (summer 2019), and Year 5 (summer 2020).

Table 7 – In Situ Water Quality Measurement Results

Site	Year	Temperature (°C)	Dissolved Oxygen (mg/L)	pH (Units)	Specific Conductance (µS/cm)	Turbidity (NTU)
Fost-1	1 (Summer 2015)	19.0	8.46	6.96	269.0	3.88
Fost-1	2 (Summer 2016)	22.0	8.86	6.92	325.6	20.9
Fost-1	3 (Summer 2017)	21.9	7.4	7.26	257.9	17.7
Fost-1	4 (Summer 2019)	23.3	8.4	7.41	263.6	13.7
Fost-1	5 (Summer 2020)	20.6	6.26	7.19	275.6	14.6
Fost-2	1 (Summer 2015)	17.2	2.13	6.57	224.2	6.47
Fost-2	2 (Summer 2016)	20.0	1.24	6.39	282.3	10.4
Fost-2	3 (Summer 2017)	20.8	5.96	6.87	222.8	66.2

Fost-2	4 (Summer 2019)	22.3	4.22	6.94	244.7	4.26
Fost-2	5 (Summer 2020)	22.6	4.48	6.77	227.9	14.5
Fost-3	1 (Summer 2015)	19.4	8.36	6.86	260.4	4.63
Fost-3	2 (Summer 2016)	18.2	7.91	6.90	247.5	4.82
Fost-3	3 (Summer 2017)	20.1	7.29	7.12	292.9	6.45
Fost-3	4 (Summer 2019)	22.0	8.26	6.82	281.6	4.91
Fost-3	5 (Summer 2020)	n/a	n/a	n/a	n/a	n/a
Fost-4	1 (Summer 2015)	18.0	6.35	6.83	112.4	10.1
Fost-4	4 (Summer 2019)	21.9	6.6	6.15	83.1	18.7
Fost-5	1 (Summer 2015)	17.1	8.76	7.48	617.0	1.44
Fost-5	4 (Summer 2019)	21.7	8.21	7.37	586.0	3.97

Shaded cells indicate values exceeding either water quality criteria or published values

MDE has established acceptable water quality standards for each designated Stream Use Classification, which are listed in the *Code of Maryland Regulations (COMAR) 26.08.02.033 - Water Quality*. Foster Branch is covered in *COMAR* in Sub-Basin 02-13-08: Gunpowder River Area as Use I waters. Specific designated uses for Use I streams include growth and propagation of fish and aquatic life, water supply for industrial and agricultural use, water contact sports, fishing, and leisure activities involving direct water contact.

The acceptable criteria for Use I waters are as follows:

- pH - 6.5 to 8.5
- DO - may not be less than 5 mg/l at any time
- Turbidity - maximum of 150 Nephelometric Turbidity Units (NTU's) and maximum monthly average of 50 NTU
- Temperature - maximum of 90°F (32°C) or ambient temperature of the surface water, whichever is greater

In situ water quality measurements for temperature, pH, and turbidity for 2015, 2016, 2017, 2019, and 2020 were within *COMAR* standards for Use I streams with the exception of Fost-2 in 2016 with a pH value of 6.39 and Fost-4 in 2019 with a pH value of 6.15. Measurement of dissolved oxygen at Fost-2 was 2.13 mg/L during the 2015 visit, 1.24 mg/L during the 2016 visit, 4.22 mg/L in 2019, and 4.48 mg/L during the 2020 visit below the Use I instantaneous criterion of 5.0 mg/L. The cause of the low dissolved oxygen measurement was likely due to the flow at this site being greatly reduced. The site was reduced to standing pools at the time of sampling during both 2015 and 2016. In 2017 the stream was flowing and the dissolved oxygen was measured at 5.96 mg/L. With no flow to bring oxygenated water into the site in 2015- 2016, biological processes had likely reduced the dissolved oxygen available in what little water existed in the site.

Although MDE does not have a water quality standard for specific conductivity, Morgan and others (Morgan et al, 2007; Morgan et al, 2012) have reported critical values for specific conductance in Maryland streams, above which there is a potential for detrimental effects on the stream biological communities. For the benthic macroinvertebrate community that critical value is 247 µS/cm, and for the fish community it is 171 µS/cm. Four of the five Foster Branch stream sites had specific conductivity values exceeding the threshold for fish community impairment, and exceedances were measured at these four sites during all *in situ* sampling events. Four of the five also had values exceeding the benthic macroinvertebrate threshold, with Fost-1 and Fost-3 exceeding during all sampling years, Fost-2 exceeding only during 2016, and Fost-5 exceeding during sampling events in 2015 and 2019. Only Fost-4 had specific conductivity below both thresholds. Conductivity levels in this watershed are likely influenced by runoff from impervious surfaces (i.e., roads, sidewalks, parking lots, roof tops). Increased stream inorganic ion concentrations (i.e., conductivity) in urban systems typically results from paved surface de-icing, accumulations in storm-water management facilities (Casey et al., 2013), runoff from impervious surfaces, passage through pipes, and exposure to other infrastructure (Cushman, 2006). Fost-4 has the lowest percentage of impervious cover of the five sites, and that low amount of impervious likely results in lower specific conductivity as fewer deicing materials are applied to the catchment upstream of this site. While elevated conductivity may not directly affect stream biota, its constituents (e.g., chloride, metals, and nutrients) may be present at levels that can cause biological impairment.

2.2 Physical Habitat Assessment

The summary results of the PHI habitat assessments are presented in Table 8. Fost-1, Fost-2 and Fost-3 all have compromised physical habitat, with PHI ratings of either 'Degraded' or 'Severely Degraded' with the exceptions of Fost-1 and Fost-2 during summer 2020 and Fost-3 during summer 2016 being rated as 'Partially Degraded'. Fost-4 and Fost-5 have had the best habitat scores of the five sites scoring 'Partially Degraded' and 'Minimally Degraded', respectively in 2015 and both 'Partially Degraded in 2019), reflecting their location in a minimally-disturbed tract of forest. The relatively low habitat scores at Fost-1, Fost-2 and Fost-3 are likely due to urbanization effects on streams. Complete physical habitat data for each site are included in Appendix A.

Table 8 – PHI Habitat Assessment Results

Site	Year	PHI Score	PHI Narrative Rating
Fost-1	1 (Summer 2015)	50.0	Severely Degraded
Fost-1	2 (Summer 2016)	58.1	Degraded
Fost-1	3 (Summer 2017)	58.9	Degraded
Fost-1	4 (Summer 2019)	61.12	Degraded
Fost-1	5 (Summer 2020)	67.59	Partially Degraded
Fost-2	1 (Summer 2015)	53.3	Degraded
Fost-2	2 (Summer 2016)	54.8	Degraded
Fost-2	3 (Summer 2017)	64.5	Degraded
Fost-2	4 (Summer 2019)	63.12	Degraded
Fost-2	5 (Summer 2020)	66.82	Partially Degraded
Fost-3	1 (Summer 2015)	60.1	Degraded
Fost-3	2 (Summer 2016)	74.8	Partially Degraded
Fost-3	3 (Summer 2017)	63.1	Degraded
Fost-3	4 (Summer 2019)	58.79	Degraded
Fost-3	5 (Summer 2020)	n/a	n/a
Fost-4	1 (Summer 2015)	78.6	Partially Degraded
Fost-4	4 (Summer 2019)	74.90	Partially Degraded
Fost-5	1 (Summer 2015)	84.9	Minimally Degraded
Fost-5	4 (Summer 2019)	78.04	Partially Degraded

2.3 Benthic Macroinvertebrate Community

The results of benthic macroinvertebrate community assessments for Year 5 are presented in Table 9. Complete benthic macroinvertebrate data for each site are included in Appendix B.

Table 9 – Benthic Index of Biotic Integrity (BIBI) Summary Data – Year 5

Metric	Fost-1	Fost-2	Fost-3	Fost-4	Fost-5
Metric Values					
Total Number of Taxa	28	18	21	10	14
Number of EPT Taxa	6	2	3	2	1
Number of Ephemeroptera Taxa	1	0	2	0	0
% Intolerant to Urban	12.40	0.00	23.33	83.97	0.00
% Ephemeroptera	10.74	0.00	18.33	0.00	0.00
Number of Scraper Taxa	4	2	4	0	2
% Climbers	9.92	3.03	16.67	2.29	1.55
Metric Scores					
Total Number of Taxa	5	3	3	1	3
Number of EPT Taxa	5	3	3	3	1
Number of Ephemeroptera Taxa	3	1	5	1	1
% Intolerant to Urban	3	1	3	5	1
% Ephemeroptera	3	1	5	1	1
Number of Scraper Taxa	5	5	5	1	5
% Climbers	5	3	5	3	3
BIBI Score	**4.14**	**2.43**	**4.14**	**2.14**	**2.14**
Narrative Rating	**Good**	**Poor**	**Good**	**Poor**	**Poor**

Foster Branch sites had BIBI ratings for Year 5 ranging from the 'Poor' to 'Good' category. Fost-1 and Fost-3 had the highest scores of 4.14 resulting in a 'Good' rating. Fost-2 had the next highest score of 2.43 resulting in a 'Poor' rating. Fost-4 and Fost-5 received the lowest scores of 2.14 resulting in a rating of 'Poor'. During Year 1, all sites except for Fost-4 had measured specific conductivity values greater than the published impairment threshold for benthic macroinvertebrates. Conversely, Fost-4 had the lowest measured specific conductivity and the highest proportion of organisms intolerant to urbanization. That pattern held true for Years 2 and 3 as well. A comparison of BIBI scores across the five years of monitoring is presented in Table 10 and Figure 2. BIBI scores in Year 5 were higher at Fost-1, Fost-2, and Fost-3 and lower at Fost-4 and Fost-5 when compared to Year 4.

Table 10 – BIBI Scores and Narrative Rating for all Years

Site	Year	BIBI Score	Narrative Rating
Fost-1	1 (Spring 2016)	2.14	Poor
Fost-1	2 (Spring 2017)	2.71	Poor
Fost-1	3 (Spring 2018)	3.00	Fair
Fost-1	4 (Spring 2019)	2.71	Poor
Fost-1	5 (Spring 2020)	4.14	Good
Fost-2	1 (Spring 2016)	2.14	Poor
Fost-2	2 (Spring 2017)	2.14	Poor
Fost-2	3 (Spring 2018)	1.86	Very Poor
Fost-2	4 (Spring 2019)	2.14	Poor
Fost-2	5 (Spring 2020)	2.43	Poor
Fost-3	1 (Spring 2016)	3.00	Fair
Fost-3	2 (Spring 2017)	2.71	Poor
Fost-3	3 (Spring 2018)	3.00	Fair
Fost-3	4 (Spring 2019)	3.00	Fair
Fost-3	5 (Spring 2020)	4.14	Good
Fost-4	1 (Spring 2016)	2.43	Poor
Fost-4	2 (Spring 2017)	2.71	Poor
Fost-4	3 (Spring 2018)	2.71	Poor
Fost-4	4 (Spring 2019)	2.43	Poor
Fost-4	5 (Spring 2020)	2.14	Poor
Fost-5	1 (Spring 2016)	1.86	Very Poor
Fost-5	2 (Spring 2017)	2.71	Poor
Fost-5	3 (Spring 2018)	2.14	Poor
Fost-5	4 (Spring 2019)	2.43	Poor
Fost-5	5 (Spring 2020)	2.14	Poor

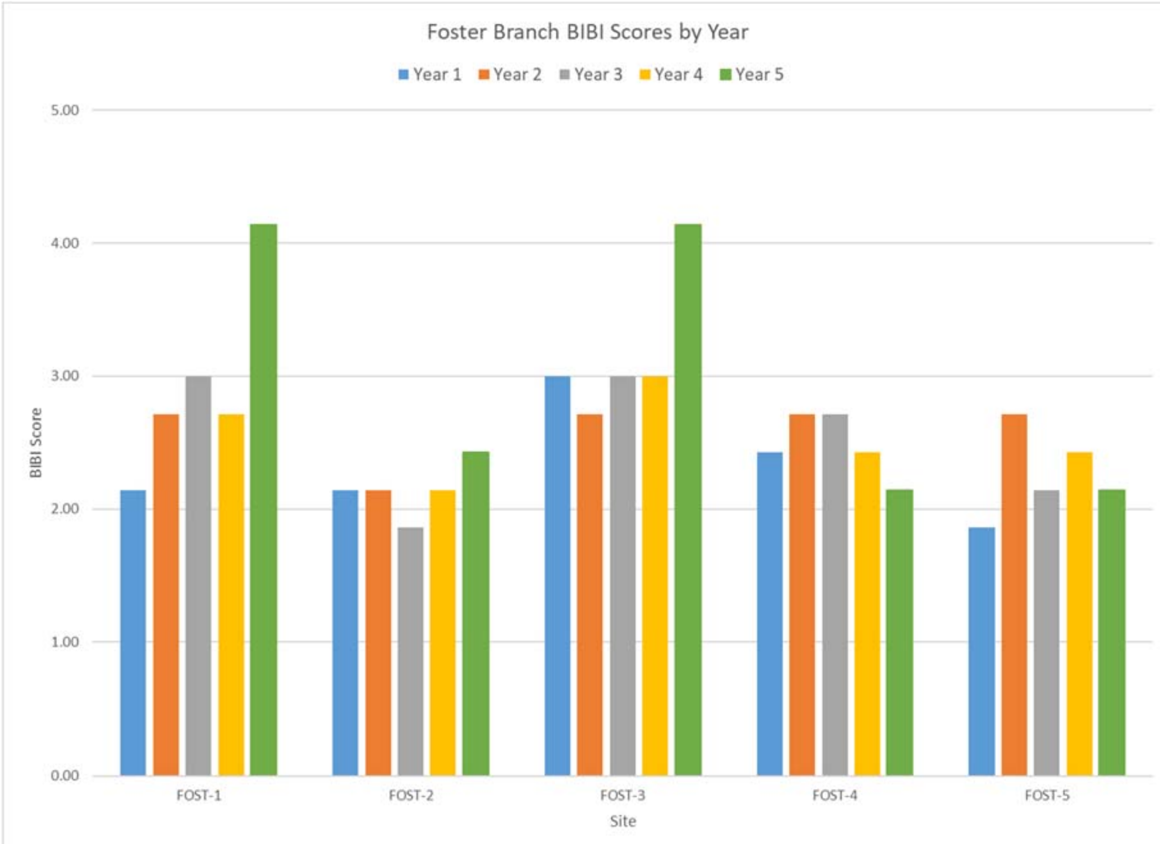

Figure 2 – BIBI Scores by Year

2.4 Fish Community

The results of the fish community assessments are presented in Table 11 and a cumulative list of species collected at each site for all years sampled can be found in Table 12. Complete fish community data for each site are included in Appendix C.

The Foster Branch sites had FIBI ratings ranging across the entire spectrum from 'Poor' to 'Good'. As noted before, sites Fost-4 and Fost-5 were only sampled in Year 1 and Year 4 as per the Foster Branch Monitoring Plan. These two sites are sufficiently small enough in contributing drainage area (each approx. 100 acres) that a Maryland-specific species-area curve suggests that very few, if any, fish species are expected to be observed; therefore fish community may not be a useful indicator of stream condition. Fost-3 was not sampled during 2020 due to the previously described beaver activity that made the site unsampleable during the entire Summer Index Period.

Table 11 – Fish Index of Biotic Integrity (FIBI) Summary Data – Year 5

Metric	Fost-1	Fost-2	Fost-3
Metric Values			
Abundance per square meter	1.00	1.15	n/a
Adjusted Number of Benthic species	1.37	0.00	n/a
% Tolerant	79.46	81.76	n/a
% Generalist, Omnivores, Invertivores	95.74	100.00	n/a
% Round-bodied Suckers	2.33	0.00	n/a
% Abundance of Dominant Taxon	36.05	0.59	n/a
Metric Scores			
Abundance per square meter	5	5	n/a
Adjusted Number of Benthic species	5	1	n/a
% Tolerant	3	3	n/a
% Generalist, Omnivores, Invertivores	3	1	n/a
% Round-bodied Suckers	5	1	n/a
% Lithophilic Spawners	5	5	n/a
FIBI Score	***4.33***	***2.67***	n/a
Narrative Rating	***Good***	***Fair***	n/a

Table 12 – Cumulative List of Fish Species Collected at Foster Branch Sites

Common Name	Scientific Name	Fost-1	Fost-2	Fost-3	Fost-4	Fost-5
Least Brook Lamprey	*Lampetra aepyptera*	X		X		
Sea Lamprey	*Petromyzon marinus*			X		
American Eel	*Anguilla rostrata*	X		X		X
Eastern Mosquitofish	*Gambusia holbrooki*	X				
Yellow Bullhead	*Ameiurus natalis*	X				
Brown Bullhead	*Ameiurus nebulosus*	X				
Creek Chubsucker	*Erimyzon oblongus*	X	X			
Northern Hogsucker	*Hypentelium nigricans*	X				
White Sucker	*Catostomus commersonii*	X	X	X		
Goldfish	*Carassius auratus*	X				
Eastern Silvery Minnow	*Hybognathus regius*	X				
Rosyside Dace	*Clinostomus funduloides*	X	X	X		X
Satinfin Shiner	*Cyprinella analostana*	X		X		
Spottail Shiner	*Notropis hudsonius*	X				
Swallowtail Shiner	*Notropis procne*	X				
Creek Chub	*Semotilus atromaculatus*	X	X	X	X	X
Blacknose Dace	*Rhinichthys atratulus*	X	X	X	X	X
Banded Killifish	*Fundulus diaphanus*	X		X		
Mummichog	*Fundulus heteroclitus*	X	X	X		X
Tessellated Darter	*Etheostoma olmstedi*	X	X	X		
Largemouth Bass	*Micropterus salmoides*	X		X		
Bluespotted Sunfish	*Enneacanthus gloriosus*	X				
Lepomis sp. (hybrid)	*Lepomis sp.*	X				
Redbreast Sunfish	*Lepomis auritus*	X		X		

Common Name	Scientific Name	Fost-1	Fost-2	Fost-3	Fost-4	Fost-5
Bluegill	*Lepomis machrochirus*	X		X		
Pumpkinseed	*Lepomis gibbosus*	X	X	X		
Green Sunfish	*Lepomis cyanellus*	X				
Northern Snakehead	*Channa spp.*	X				

Site Fost-1 had the highest FIBI score between the two sites with, 4.33 which rated 'Good'. Twelve species of fish were collected during Year 5 at Fost-1, the highest diversity of the two sites. The diversity of fish collected at this site helped to drive the FIBI score into the 'Good' category. Larger stream sites along the Fall Line between Maryland's Piedmont and Coastal Plain have a larger potential pool of species, possibly being occupied by species more commonly associated with one or the other physiographic provinces.

Fost-2 had a FIBI score of 2.67 in Year 5 which was in the 'Poor' category. Seven species were collected during Year 5 sampling, the most of all sampling years. This site was previously only standing pools during both the summer of 2015 and 2016, which reduced greatly the space and resources available to stream fish. In 2017 the entire site had flow going through it which most likely resulted in the increase in FIBI score. This site also had flow through the entire site during 2019 and 2020

A comparison of FIBI scores across the five years of monitoring is presented in Table 13 and Figure 3. Fost-1 had the same FIBI score in Year 5 as Year 4, a 4.33. Fost-2 scored a 2.67, a decrease of (-0.66) from Year 4. During the first two years of sampling at Fost-2 the site was reduced to standing pools. This lack of water and habitat space likely is the cause of the low FIBI scores during those years. Site Fost-3 was not sampled in Year 5 due to unsamplable conditioned. Site Fost-3 had a lower FIBI score (-0.34) in Year 4 than in Year 3, a 3.33 vs a 3.67. Sites Fost-4 and Fost-5 were only sampled during Years 1 and 4. These sites are small headwater streams which were outlined in the Foster Branch Monitoring Plan as being sampled less frequently as the rest of the Foster Branch sites. Fost-4 remained the same between the four years at 1.67. Fost-5 decreased by (-0.34) in Year 4 compared to Year 1.

Table 13 – FIBI Scores and Narrative Rating Across Years

Site	Year	FIBI Score	Narrative Rating
Fost-1	1 (Summer 2015)	4.67	Good
Fost-1	2 (Summer 2016)	5.00	Good
Fost-1	3 (Summer 2017)	4.33	Good
Fost-1	4 (Summer 2019)	4.33	Good
Fost-1	5 (Summer 2020)	4.33	Good
Fost-2	1 (Summer 2015)	1.00	Very Poor
Fost-2	2 (Summer 2016)	1.00	Very Poor
Fost-2	3 (Summer 2017)	1.67	Very Poor
Fost-2	4 (Summer 2019)	3.33	Fair
Fost-2	5 (Summer 2020)	2.67	Poor
Fost-3	1 (Summer 2015)	4.33	Good
Fost-3	2 (Summer 2016)	3.33	Fair
Fost-3	3 (Summer 2017)	3.67	Fair
Fost-3	4 (Summer 2019)	3.33	Fair
Fost-3	5 (Summer 2020)	n/a	n/a
Fost-4	1 (Summer 2015)	1.67	Very Poor
Fost-4	4 (Summer 2019)	1.67	Very Poor
Fost-5	1 (Summer 2015)	2.67	Poor
Fost-5	4 (Summer 2019)	2.33	Poor

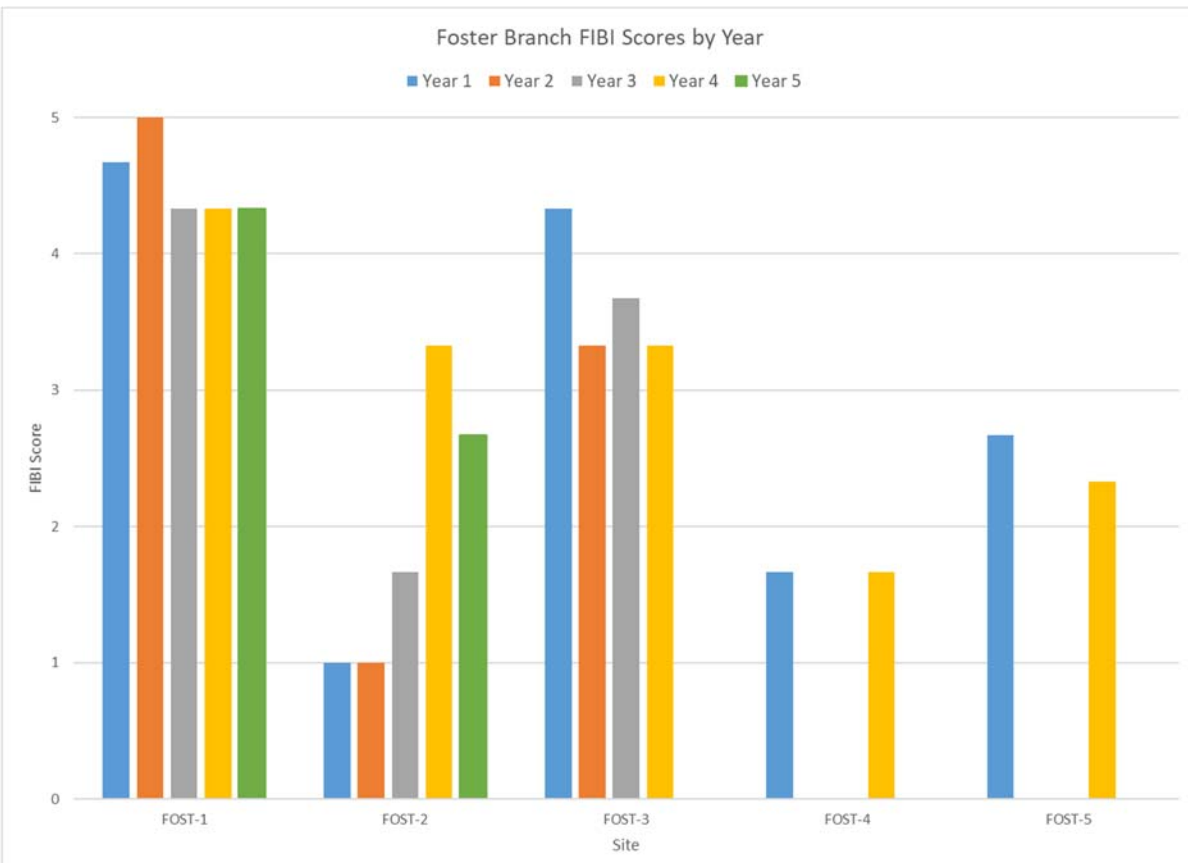

Figure 3 – FIBI Scores by Year

2.5 Herpetofauna

At least two amphibian species have been documented at each of the sites over the five year sampling period. Table 14 shows the cumulative presence of herpetofauna over all five years of sampling. Fost-1 has the highest diversity with six species present at the site. The most widely distributed species was Northern Green Frog, which was present at all five of the Foster Branch sites. Stream salamander species were observed at three of the five sites during the stream salamander search or incidentally during other sampling activities. Northern Two-lined Salamander was observed at Fost-2 during the summer 2015 field visit, at Fost-1 during the summer 2016 visit, and at Fost-5 during both summer 2015 and summer 2016. At Fost-1 and Fost-2 a single individual was captured during electrofishing activities, but none were observed during the targeted stream salamander search. At Fost-5 one individual was observed while electrofishing during the summer 2015 sampling event but no salamanders were encountered during the targeted stream salamander search. During summer of 2016 no electrofishing took place at Fost-5 but one individual was encountered during the stream salamander search. During summer 2017, 2019, and 2020, no salamanders were encountered incidentally or during the stream salamander search.

Table 14 – Cumulative Herpetofauna Presence at Foster Branch Sites

Common Name	Scientific Name	Fost-1	Fost-2	Fost-3	Fost-4	Fost-5
Cope's Gray Treefrog	*Hyla chrysoscelis*			X	X	
American Bullfrog	*Lithobates catesbeianus*	X	X			
Northern Green Frog	*Lithobates clamitans melanota*	X	X	X	X	X
Pickerel Frog	*Lithobates palustris*	X	X	X		
Northern Spring Peeper	*Pseudacris crucifer*	X				
Northern Watersnake	*Nerodia sipedon sipedon*	X				
Stream Salamanders						
Northern Two-lined Salamander	*Eurycea bislineata*	X	X			X

The low density of stream salamanders at three sites, and lack of stream salamanders at two of the five sites is likely due to a combination of habitat degradation and water quality impairment. There was very little suitable stream salamander habitat present at those sites for the field crew to search. The restoration reach (Fost-1) contained several areas of armored banks and rock structures in the stream. Those areas are not preferred habitat for stream salamanders. The non-restored sites had a dominant substrate of sand which is not a preferred habitat of stream salamanders. Stream salamanders generally prefer large cover objects over loose cobble and gravel, creating a moist microclimate and many interstices for shelter and foraging. Stream salamanders breathe through their highly permeable skin and are therefore particularly sensitive to water quality impairments. The high conductivity values suggest that salamanders would experience osmotic difficulties in these conditions.

2.6 Freshwater Mussels

No freshwater mussels were observed at any Foster Branch site during sampling to date. The lack of freshwater mussels at these sites is likely due to a combination of habitat degradation and water quality impairment. Freshwater mussels are relatively sessile organisms which live partially embedded within the stream substrates. The flashy hydrology characteristic of urban streams like Foster Branch create habitat conditions unsuitable for freshwater mussels. Also, it is likely that water quality conditions in urban streams are outside the range of tolerance of these sensitive organisms.

2.7 Crayfish

Crayfish were observed at both of the Foster Branch sites. *Faxonius limosus*, a native species, was observed at Fost-1 during electrofishing in all five years and at Fost-3 during Year 2 and Year 3. In 2019 and 2020, *Procambarus sp.* was found at both Fost-1 and Fost-2. Crayfish burrows were not observed at any of the Foster Branch sites during Year 5. In previous years, crayfish burrows were observed at all of the Foster Branch sites during all four years of sampling. These burrows most likely were dug by *Cambarus diogenes*, but no specimens were collected to confirm. *Cambarus diogenes* is the most likely species as it is the only burrowing species collected by MD DNR in Harford County. The lack of crayfish may be due to habitat degradation. Both Fost-2 and Fost-3 have had evidence of high flows noted on datasheets, suggesting that flashy urban hydrology may frequently disturb cover objects reducing the availability of suitable crayfish habitat at those sites. Water quality conditions may also be impacting crayfish, but currently the water quality requirements for crayfish in Maryland are poorly understood.

2.8 Invasive Plant Species

Invasive plant species were present at all of the Foster Branch sites. Table 15 presents all invasive species found at each monitoring site cumulatively for all sampling visits. Fost-2 has the most invasive plant species with eight, and Fost-4 had the least with two. Japanese stiltgrass was the most widely distributed invasive plant, found at all five sites. Oriental bittersweet and Multiflora rose were the next most widely distributed species, each being found at four sites.

Table 15 – Cumulative Invasive Plant Species Presence at Foster Branch Sites

Common Name	Scientific Name	Fost-1	Fost-2	Fost-3	Fost-4	Fost-5
Garlic mustard	*Alliaria petiolata*		X			
Japanese barberry	*Berberis thunbergii*					X
Oriental bittersweet	*Celastrus orbiculatus*		X	X	X	X
Autumn olive	*Elaeagnus umbellata*			X		
American wintergreen	*Gaultheria procumbens*		X			
Ground Ivy	*Glechoma hederacea*	X	X			
Chinese Lespedeza	*Lespedeza cuneata*	X				
Privet	*Ligustrum sp.*	X	X			
Japanese honeysuckle	*Lonicera japonica*		X			X
Japanese stiltgrass	*Microstegium vimineum*	X	X	X	X	X
Mile-a-minute	*Persicaria perfoilata*					X
Phragmites	*Phragmites sp.*	X				
Multiflora rose	*Rosa multiflora*	X	X	X		X

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Appendix A: Physical Habitat Data

Project Name: Foster's Branch Biological Monitoring
Project Number: 161602035.03
Prepared by: SLF
Prepared date: 10/21/2020

PHI_Coastal_Plain_v2_Fosters_2020_v2.xlsx

		Raw Data											Scaled Metrics						Rating	
Site	Subshed Area (acres)	Instream Habitat	Epifaunal Substrate	Velocity Depth Diversity	Pool Glide Eddy Quality	Bank Stab (0-20)	Embeddedness	Percent Shading	Aesthetics (Trash)	Remoteness Score	# Woody Debris/ Rootwads	Max Depth	Instream Habitat	Epifaunal Substrate	Bank Stability	Shading	Remoteness	# Woody Debris/ Rootwads	PHI	PHI Rating
FOST-1	1137.51	14	12	12	13	17	35	55	18	7	4	84	86.35	80.08	93.10	54.42	37.70	53.88	67.59	Partially Degraded
FOST-2	398.06	8	7	11	12	10	80	90	15	3	21	52	63.81	57.88	71.77	91.34	16.16	100.00	66.82	Partially Degraded

Score	Narrative Rating
81-100	Minimally Degraded
66.0-80.9	Partially Degraded
51.0-65.9	Degraded
0-50.9	Severely Degraded

Appendix B: Benthic Macroinvertebrate Data

Project Name:	Foster Branch			Foster_2020_BIBI_Coastal_Plain_v4.xlsx
Project Number:	161602035.03			Version:
Prepared by:	SLF	Checked by:	RAO	
Prepared date:	10/5/2020	Checked date:	12/22/2020	

KCI TECHNOLOGIES

Metric	Fost-1	Fost-2	Fost-3	Fost-4	Fost-5
Raw Scores	**Raw Scores**				
Total Number of Taxa	28	18	21	10	14
Number of EPT Taxa	6	2	3	2	1
Number Ephemeroptera Taxa	1	0	2	0	0
Percent Intolerant Urban	12.40	0.00	23.33	83.97	0.00
Percent Ephemeroptera	10.74	0.00	18.33	0.00	0.00
Number Scraper Taxa	4	2	4	0	2
Percent Climbers	9.92	3.03	16.67	2.29	1.55
BIBI Scores	**BIBI Scores**				
Total Number of Taxa	5	3	3	1	3
Number of EPT Taxa	5	3	3	3	1
Number Ephemeroptera Taxa	3	1	5	1	1
Percent Intolerant Urban	3	1	3	5	1
Percent Ephemeroptera	3	1	5	1	1
Number Scraper Taxa	5	5	5	1	5
Percent Climbers	5	3	5	3	3
BIBI Score	***4.14***	***2.43***	***4.14***	***2.14***	***2.14***
Narrative Rating	***Good***	***Poor***	***Good***	***Poor***	***Poor***

Coastal Plain (CP) Scoring Criteria		Score	
Metric	**5**	**3**	**1**
Total Number of Taxa	≥22	14-21	<14
Number of EPT Taxa	≥5	2-4	<2
Number Ephemeroptera Taxa	≥2	1-1	<1
Percent Intolerant Urban	≥28	10-27	<10
Percent Ephemeroptera	≥11.0	0.8-10.9	<0.8
Number Scraper Taxa	≥2	1-1	<1
Percent Climbers	≥8.0	0.9-7.9	<0.9

Project Name: Foster Branch
Project Number: 161602035.03
Prepared by: SLF   Checked by: RAO
Prepared date: 10/5/2020   Checked date: 12/22/2020

Foster_2020_BIBI_Coastal_Plain_v4.xlsx
Version: 4
Site Name: FOST-1

KCI TECHNOLOGIES

Subphylum/ Class	Order	Family	Genus	Final ID	Note[1]	# of Org	FFG[2]	Habit[3]	Tolerance Value[4]
Oligochaeta	Haplotaxida	Naididae	not identified	Naididae	U	13	Collector	bu	8.5
Oligochaeta	Lumbriculida	Lumbriculidae	not identified	Lumbriculidae	U	3	Collector	bu	6.6
Oligochaeta	Tubificida	Tubificidae	not identified	Tubificidae	U	23	Collector	cn	8.4
Insecta	Coleoptera	Dryopidae	Helichus	Helichus	A	1	Scraper	cn	6.4
Insecta	Coleoptera	Elmidae	Stenelmis	Stenelmis	I/A	6	Scraper	cn	7.1
Insecta	Diptera	Chironomidae	Cricotopus	Cricotopus	I	5	Shredder	cn, bu	9.6
Insecta	Diptera	Chironomidae	Parametriocnemus	Parametriocnemus	I	6	Collector	sp	4.6
Insecta	Diptera	Chironomidae	Paratanytarsus	Paratanytarsus	I	1	Collector	sp	7.7
Insecta	Diptera	Chironomidae	Polypedilum	Polypedilum	I	6	Shredder	cb, cn	6.3
Insecta	Diptera	Chironomidae	Rheotanytarsus	Rheotanytarsus	I	1	Filterer	cn	7.2
Insecta	Diptera	Chironomidae	Tanytarsus	Tanytarsus	I	3	Filterer	cb, cn	4.9
Insecta	Diptera	Chironomidae	Tribelos	Tribelos	I	6	Collector	bu	7
Insecta	Diptera	Chironomidae	Tvetenia	Tvetenia	I	5	Collector	sp	5.1
Insecta	Diptera	Empididae	Hemerodromia	Hemerodromia	I	1	Predator	sp, bu	7.9
Insecta	Diptera	Simuliidae	Prosimulium	Prosimulium	I	1	Filterer	cn	2.4
Insecta	Diptera	Tipulidae	Antocha	Antocha	I	1	Collector	cn	8
Insecta	Ephemeroptera	Baetidae	Acerpenna	Acerpenna	I	13	Collector	sw, cn	2.6
Insecta	Odonata	Calopterygidae	Calopteryx	Calopteryx	I	1	Predator	cb	8.3
Insecta	Odonata	Coenagrionidae	Argia	Argia	I	1	Predator	cn, cb, sp	9.3
Insecta	Odonata	not identified	not identified	Odonata	I	1	Predator	0	6.6
Insecta	Plecoptera	Nemouridae	not identified	Nemouridae	I	1	Shredder	sp, cn	2.9
Insecta	Trichoptera	Hydropsychidae	Cheumatopsyche	Cheumatopsyche	I	6	Filterer	cn	6.5
Insecta	Trichoptera	Hydropsychidae	Hydropsyche	Hydropsyche	I	8	Filterer	cn	7.5
Insecta	Trichoptera	Hydroptilidae	Hydroptila	Hydroptila	I	2	Scraper	cn	6
Insecta	Trichoptera	Philopotamidae	Chimarra	Chimarra	I	3	Filterer	cn	4.4
Malacostraca	Amphipoda	Crangonyctidae	Crangonyx	Crangonyx	U	1	Collector	sp	6.7
Gastropoda	Basommatophor	Physidae	Physella	Physella	U	1	Scraper	cb	8
0	0	0	not identified	Nematoda	U	1	0	0	na

1 Life Stage, I - Immature, P- Pupa, A - Adult, U - Undetermined; 2 Functional Feeding Group; 3 Primary habit or form of locomotion, includes bu - burrower, cn - clinger, cb - climber, sk - skater, sp - sprawler, sw - swimmer; 4 Tolerance Values, based on Hilsenhoff, modified for Maryland. An entry of "0" indicates information for the particular taxa was not available.

Project Name: Foster Branch
Project Number: 161602035.03
Prepared by: SLF
Prepared date: 10/5/2020

Checked by: RAO
Checked date: 12/22/2020

Foster_2020_BIBI_Coastal_Plain_v4.xlsx
Version: 4
Site Name: FOST-2

Subphylum/ Class	Order	Family	Genus	Final ID	Note[1]	# of Org	FFG[2]	Habit[3]	Tolerance Value[4]
Oligochaeta	Haplotaxida	Naididae	not identified	Naididae	U	50	Collector	bu	8.5
Oligochaeta	Tubificida	Tubificidae	not identified	Tubificidae	I	18	Collector	cn	8.4
Insecta	Diptera	Chironomidae	Hydrobaenus	Hydrobaenus	I	25	Scraper	sp	7.2
Insecta	Diptera	Chironomidae	Natarsia	Natarsia	I	2	Predator	sp	6.6
Insecta	Diptera	Chironomidae	Orthocladius	Orthocladius	I	15	Collector	sp, bu	9.2
Insecta	Diptera	Chironomidae	Paratendipes	Paratendipes	I	1	Collector	bu	6.6
Insecta	Diptera	Chironomidae	Polypedilum	Polypedilum	I	2	Shredder	cb, cn	6.3
Insecta	Diptera	Chironomidae	Sympotthastia	Sympotthastia	I	1	Collector	sp	8.2
Insecta	Diptera	Chironomidae	Tanytarsus	Tanytarsus	I	1	Filterer	cb, cn	4.9
Insecta	Diptera	Simuliidae	Simulium	Simulium	I	1	Filterer	cn	5.7
Insecta	Odonata	not identified	not identified	Odonata	I	1	Predator	0	6.6
Insecta	Trichoptera	Hydropsychidae	Cheumatopsyche	Cheumatopsyche	I	1	Filterer	cn	6.5
Insecta	Trichoptera	Hydropsychidae	Hydropsyche	Hydropsyche	I	1	Filterer	cn	7.5
Malacostraca	Amphipoda	Crangonyctidae	Crangonyx	Crangonyx	U	5	Collector	sp	6.7
Bivalvia	Veneroida	Pisidiidae	not identified	Sphaeriidae	I	1	Filterer	bu	6.5
Bivalvia	Veneroida	Pisidiidae	Pisidium	Pisidium	I	3	Filterer	bu	5.7
Gastropoda	Basommatophora	Physidae	Physella	Physella	U	1	Scraper	cb	8
0	0	0	not identified	Nematoda	U	1	0	0	na
Enopla	Hoplonemertea	Tetrastemmatidae	Prostoma	Prostoma	U	2	Predator	0	7.3

1 Life Stage, I - Immature, P- Pupa, A - Adult, U - Undetermined; 2 Functional Feeding Group; 3 Primary habit or form of locomotion, includes bu - burrower, cn - clinger, cb - climber, sk - skater, sp - sprawler, sw - swimmer; 4 Tolerance Values, based on Hilsenhoff, modified for Maryland. An entry of "0" indicates information for the particular taxa was not available.

Project Name: Foster Branch
Project Number: 161602035.03
Prepared by: SLF   Checked by: RAO
Prepared date: 10/5/2020   Checked date: 12/22/2020

Foster_2020_BIBI_Coastal_Plain_v4.xlsx
Version: 4
Site Name: FOST-3

KCI TECHNOLOGIES

Subphylum/ Class	Order	Family	Genus	Final ID	Note[1]	# of Org	FFG[2]	Habit[3]	Tolerance Value[4]
Oligochaeta	Haplotaxida	Naididae	not identified	Naididae	U	4	Collector	bu	8.5
Oligochaeta	Tubificida	Tubificidae	not identified	Tubificidae	U	3	Collector	cn	8.4
Insecta	Coleoptera	Elmidae	Ancyronyx	Ancyronyx	I/A	2	Scraper	cn, sp	7.8
Insecta	Coleoptera	Elmidae	Dubiraphia	Dubiraphia	I	1	Scraper	cn, cb	5.7
Insecta	Coleoptera	Elmidae	Stenelmis	Stenelmis	I/A	3	Scraper	cn	7.1
Insecta	Diptera	Chironomidae	Ablabesmyia	Ablabesmyia	I	8	Predator	sp	8.1
Insecta	Diptera	Chironomidae	Corynoneura	Corynoneura	I/P	6	Collector	sp	4.1
Insecta	Diptera	Chironomidae	Micropsectra	Micropsectra	I	5	Collector	cb, sp	2.1
Insecta	Diptera	Chironomidae	Paratanytarsus	Paratanytarsus	I	10	Collector	sp	7.7
Insecta	Diptera	Chironomidae	Polypedilum	Polypedilum	I	12	Shredder	cb, cn	6.3
Insecta	Diptera	Chironomidae	Rheocricotopus	Rheocricotopus	I	5	Collector	sp	6.2
Insecta	Diptera	Chironomidae	Rheosmittia	Rheosmittia	I	20	0	0	6.6
Insecta	Diptera	Chironomidae	Rheotanytarsus	Rheotanytarsus	I	5	Filterer	cn	7.2
Insecta	Diptera	Chironomidae	Sympotthastia	Sympotthastia	I	1	Collector	sp	8.2
Insecta	Diptera	Chironomidae	Thienemannimyia group	Thienemannimyia Group	I	5	Predator	sp	8.2
Insecta	Diptera	Simuliidae	Prosimulium	Prosimulium	I	1	Filterer	cn	2.4
Insecta	Ephemeroptera	Baetidae	Acerpenna	Acerpenna	I	20	Collector	sw, cn	2.6
Insecta	Ephemeroptera	Baetidae	Centroptilum	Centroptilum	I	2	Collector	sw, cn	2.3
Insecta	Odonata	Coenagrionidae	Argia	Argia	I	2	Predator	cn, cb, sp	9.3
Insecta	Odonata	not identified	not identified	Odonata	I	4	Predator	0	6.6
Insecta	Trichoptera	Psychomyiidae	Lype	Lype	I	1	Scraper	cn	4.7

1 Life Stage, I - Immature, P- Pupa, A - Adult, U - Undetermined; 2 Functional Feeding Group; 3 Primary habit or form of locomotion, includes bu - burrower, cn - clinger, cb - climber, sk - skater, sp - sprawler, sw - swimmer; 4 Tolerance Values, based on Hilsenhoff, modified for Maryland. An entry of "0" indicates information for the particular taxa was not available.

Project Name: Foster Branch
Project Number: 161602035.03
Prepared by: SLF
Prepared date: 10/5/2020

Checked by: RAO
Checked date: 12/22/2020

Foster_2020_BIBI_Coastal_Plain_v4.xlsx
Version: 4
Site Name: FOST-4

Subphylum/ Class	Order	Family	Genus	Final ID	Note[1]	# of Org	FFG[2]	Habit[3]	Tolerance Value[4]
Oligochaeta	Haplotaxida	Naididae	not identified	Naididae	U	2	Collector	bu	8.5
Insecta	Diptera	Ceratopogonidae	not identified	Ceratopogonidae	I	1	Predator	sp, bu	3.6
Insecta	Diptera	Chironomidae	Micropsectra	Micropsectra	I	2	Collector	cb, sp	2.1
Insecta	Diptera	Chironomidae	Parametriocnemus	Parametriocnemus	I	12	Collector	sp	4.6
Insecta	Diptera	Chironomidae	Thienemannimyia gr	Thienemannimyia Group	I	1	Predator	sp	8.2
Insecta	Diptera	Simuliidae	Stegopterna	Stegopterna	I	106	Filterer	cn	2.4
Insecta	Diptera	Tipulidae	Tipula	Tipula	I	2	Shredder	bu	6.7
Insecta	Plecoptera	Nemouridae	not identified	Nemouridae	I	2	Shredder	sp, cn	2.9
Insecta	Trichoptera	Limnephilidae	not identified	Limnephilidae	I	1	Shredder	cb, sp, cn	3.4
Enopla	Hoplonemertea	Tetrastemmatidae	Prostoma	Prostoma	U	2	Predator	0	7.3

1 Life Stage, I - Immature, P- Pupa, A - Adult, U - Undetermined; 2 Functional Feeding Group; 3 Primary habit or form of locomotion, includes bu - burrower, cn - clinger, cb - climber, sk - skater, sp - sprawler, sw - swimmer; 4 Tolerance Values, based on Hilsenhoff, modified for Maryland. An entry of "0" indicates information for the particular taxa

Project Name: Foster Branch
Project Number: 161602035.03
Prepared by: SLF
Prepared date: 10/5/2020

Checked by: RAO
Checked date: 12/22/2020

Foster_2020_BIBI_Coastal_Plain_v4.xlsx
Version: 4
Site Name: FOST-5

Subphylum/ Class	Order	Family	Genus	Final ID	Note[1]	# of Org	FFG[2]	Habit[3]	Tolerance Value[4]
Oligochaeta	Haplotaxida	Naididae	not identified	Naididae	U	88	Collector	bu	8.5
Oligochaeta	Lumbricina	not identified	not identified	Lumbricina	U	1	Collector	bu	na
Oligochaeta	Tubificida	Tubificidae	not identified	Tubificidae	U	1	Collector	cn	8.4
Insecta	Diptera	Ceratopogonidae	not identified	Ceratopogonidae	I	1	Predator	sp, bu	3.6
Insecta	Diptera	Chironomidae	Corynoneura	Corynoneura	I	5	Collector	sp	4.1
Insecta	Diptera	Chironomidae	Cryptochironomus	Cryptochironomus	I	2	Predator	sp, bu	7.6
Insecta	Diptera	Chironomidae	Diplocladius	Diplocladius	I	5	Collector	sp	5.9
Insecta	Diptera	Chironomidae	Hydrobaenus	Hydrobaenus	I	5	Scraper	sp	7.2
Insecta	Diptera	Chironomidae	Orthocladius	Orthocladius	I	5	Collector	sp, bu	9.2
Insecta	Diptera	Chironomidae	Polypedilum	Polypedilum	I	1	Shredder	cb, cn	6.3
Insecta	Diptera	Chironomidae	Rheosmittia	Rheosmittia	I	11	0	0	6.6
Insecta	Diptera	Empididae	Hemerodromia	Hemerodromia	I	2	Predator	sp, bu	7.9
Insecta	Trichoptera	Philopotamidae	Chimarra	Chimarra	I	1	Filterer	cn	4.4
Gastropoda	Basommatophor	Physidae	Physella	Physella	I	1	Scraper	cb	8

1 Life Stage, I - Immature, P- Pupa, A - Adult, U - Undetermined; 2 Functional Feeding Group; 3 Primary habit or form of locomotion, includes bu - burrower, cn - clinger, cb - climber, sk - skater, sp - sprawler, sw - swimmer; 4 Tolerance Values, based on Hilsenhoff, modified for Maryland. An entry of "0" indicates information for the particular taxa was not available.

Appendix C: Fish Data

Project Name:	Foster Branch Monitoring 2020		
Project Number:	161602035.03		
Prepared by:	SLF	Checked by:	RAO
Prepared date:	10/22/2020	Checked date:	12/17/2020

FIBI_Fosters_2020_CoastalPlain_v1.xlsx
Version: 1

Metric	Fost 1	Fost 2	Fost 3	Fost 4	Fost 5
Raw Scores	**Raw Scores**				
Abundance per square meter	1.00	1.15	-	-	-
Adjusted Number of Benthic species	1.37	0.00	-	-	-
% Tolerant	79.46	81.76	-	-	-
% Generalist, Omnivores, Invertivores	95.74	100.00	-	-	-
% Round Bodied Suckers	2.33	0.00	-	-	-
% Abundance of Dominant Taxon	36.05	0.59	-	-	-
FIBI Scores	**FIBI Scores**				
Abundance per square meter	5	5	-	-	-
Adjusted Number of Benthic species	5	1	-	-	-
% Tolerant	3	3	-	-	-
% Generalist, Omnivores, Invertivores	3	1	-	-	-
% Round Bodied Suckers	5	1	-	-	-
% Abundance of Dominant Taxon	5	5	-	-	-
FIBI Score	***4.33***	***2.67***	***Not Sampled***	***Not Sampled***	***Not Sampled***
Narrative Rating	***Good***	***Poor***	***Not Sampled***	***Not Sampled***	***Not Sampled***
			This site unsampleable during summer of 2020 due to beaver activity impounding site	This site not sampled during 2020; see Foster Branch monitoring plan for details	This site not sampled during 2020; see Foster Branch monitoring plan for details

Coastal Plain Metric	**Score 5**	**3**	**1**
Abundance per square meter	≥ 0.72	0.45 – 0.71	< 0.45
Adjusted Number of Benthic species	≥ 0.22	0.01 – 0.21	0
% Tolerant	≤ 68	69 –97	> 97
% Generalist, Omnivores, Invertivores	≤ 92	93 - 99	100
% Round Bodied Suckers	≥ 2	1	0
% Abundance of Dominant Taxon	≤ 40	41 - 69	> 69

Project Name: Foster Branch Monitoring 2020
Project Number: 161602035.03
Prepared by: SLF Checked by: RAO
Prepared date: 10/21/2020 Checked date: 12/17/2020

FIBI_Fosters_2020_CoastalPlain_v1.xlsx

Site Name: Fost 1

Final ID	Scientific Name	Number of Organisms	Tolerance	Trophic Status	Lithophilic Spawner	Composition	% Tolerant	% Generalists, Omnivores, Invertivores	Lithophilic Spawner	Adjusted No. Benthic Species	% Dominant Taxa	Abundance per Square Meter	Biomass per Square Meter	% Round Bodied Suckers
Brown Bullhead	*Ameiurus nebulosus*	60	T	OM	N	NOTYPE	60	60	0	0	0	0.23		0
Pumpkinseed	*Lepomis gibbosus*	93	T	IV	N	NOTYPE	93	93	0	0	93	0.36		0
Tessellated Darter	*Etheostoma olmstedi*	18	T	IV	N	B	18	18	0	1	0	0.07		0
American Eel	*Anguilla rostrata*	37	NOTYPE	GE	N	NOTYPE	0	37	0	0	0	0.14		0
Largemouth Bass	*Mictopterus salmoides*	4	T	TP	N	NOTYPE	4	0	0	0	0	0.02		0
White Sucker	*Catostomus commersonii*	16	T	OM	Y	NOTYPE	16	16	16	0	0	0.06		0
Creek Chubsucker	*Erimyzon oblongus*	6	NOTYPE	IV	N	R	0	6	0	0	0	0.02		6
Bluegill	*Lepomis macrochirus*	13	T	IV	N	NOTYPE	13	13	0	0	0	0.05		0
Redbreast Sunfish	*Lepomis auritus*	3	NOTYPE	GE	N	NOTYPE	0	3	0	0	0	0.01		0
Least Brook Lamprey	*Lampetra aepyptera*	6	NOTYPE	FF	N	B	0	0	0	1	0	0.02		0
Northern Snakehead	*Channa sp.*	1	NOTYPE	TP	N	NOTYPE	0	0	0	0	0	0.00		0
Green Sunfish	*Lepomis cyanellus*	1	T	GE	N	NOTYPE	1	1	0	0	0	0.00		0
	Total Count	*258*					*79.46*	*95.74*	*6.20*	*1.4*	*36.05*	*1.00*	*12.17*	*2.33*
	Total Biomass (g)	*3126*												

Project Name:	Foster Branch Monitoring 2020		
Project Number:	161602035.03		
Prepared by:	SLF	Checked by:	RAO
Prepared date:	10/22/2020	Checked date:	12/17/2020

FIBI_Fosters_2020_CoastalPlain_v1.xlsx

Site Name: Fost 2

Final ID	Scientific Name	Number of Organisms	Tolerance	Trophic Status	Lithophilic Spawner	Composition	% Tolerant	% Generalists, Omnivores, Invertivores	Lithophilic Spawner	Adjusted No. Benthic Species	% Dominant Taxa	Abundance per Square Meter	Biomass per Square Meter	% Round Bodied Suckers
Blacknose Dace	*Rhinichthys atratulus*	11	T	OM	N	NOTYPE	11	11	0	0	0	0.07		
Creek Chub	*Semotilus atromaculatus*	122	T	GE	Y	NOTYPE	122	122	122	0	0	0.82		
Creek Chubsucker	*Erimyzon oblongus*	26	NOTYPE	IV	N	R	0	26	0	0	0	0.18		
Pumpkinseed	*Lepomis gibbosus*	5	T	IV	N	NOTYPE	5	5	0	0	0	0.03		
Redbreast Sunfish	*Lepomis auritus*	2	NOTYPE	GE	N	NOTYPE	0	2	0	0	0	0.01		
Rosyside Dace	*Clinostomus funduloides*	3	NOTYPE	IV	Y	NOTYPE	0	3	3	0	0	0.02		
White Sucker	*Catostomus commersonii*	1	T	OM	Y		1	1	1	0	1	0.01		
	Total Count	*170*					*81.76*	*100.00*	*74.12*	*0.0*	*0.59*	*1.15*	*4.66*	*0.00*
	Total Biomass (g)	*691*												

Project Name: Foster Branch Monitoring 2020
Project Number: 161602035.03
Prepared by: SLF Checked by: AJB
Prepared date: 10/22/2020 Checked date: 12/23/2020

FIBI_Fosters_2020_CoastalPlain_v1.xlsx

Site Name: Fost 3

Final ID	Scientific Name	Number of Organisms	Tolerance	Trophic Status	Lithophilic Spawner	Composition	% Tolerant	% Generalists, Omnivores, Invertivores	Lithophilic Spawner	Adjusted No. Benthic Species	% Dominant Taxa	Abundance per Square Meter	Biomass per Square Meter	% Round Bodied Suckers
N/A						NOTYPE								
N/A						NOTYPE								
	Total Count	*0*					*#DIV/0!*	*#DIV/0!*	*#DIV/0!*	*0.0*	*#DIV/0!*		*#VALUE!*	*#DIV/0!*
	Total Biomass (g)	*This site unsampleable during summer of 2020 due to beaver activity impounding site*												

Appendix D: Supplemental Flora/Fauana Data

Fost-1

Invasive Plants	Relative Abundance
multiflora rose	Present
Japanese stiltgrass	Present
Phragmites	Present
privet	Present
ground ivy	Present

Stream Salamanders
None observed

Other Herpetofauna
Northern green frog
Northern water snake

Crayfish
Faxonius limosus
Procambarus sp.

Fost-2

Invasive Plants	Relative Abundance
Japanese stiltgrass	Present
multiflora rose	Present
ground ivy	Present
oriental bittersweet	Present
creeping wintergreen	Present
privet sp.	Present

Stream Salamanders
None observed

Other Herpetofauna
pickerel frog
northern green frog

Crayfish
Procambarus sp.

Plumtree Run

Year 5 - 2020 Monitoring Results

December | 2020

Prepared For

Harford County
Watershed Protection and Restoration
Department of Public Works
212 South Bond Street, 1st Floor
Bel Air, Maryland 21014

Prepared By

KCI Technologies, Inc.
936 Ridgebrook Road
Sparks, MD 21152

CONTENTS

TABLES

FIGURES

APPENDICES

Background and Objectives

Harford County Department of Public Works (DPW) commissioned a watershed action plan for the Plumtree Run watershed. The Plumtree Run Small Watershed Action Plan (BayLand 2011) was completed in June of 2011. The plan outlines restoration projects and storm-water retrofits throughout this approximately 1,650 acre watershed. In anticipation of the permit conditions which may be placed on these restoration projects by Maryland Department of the Environment (MDE) and the U.S. Army Corps of Engineers (USACE), a monitoring plan was developed for the Plumtree watershed.

KCI Technologies, Inc. completed the fifth year of chemical, physical, and biological stream sampling in spring and summer of 2020 at the five stream sites described in the plan. This technical memorandum describes the methods and results of the five years of sampling conducted at those sites in the Plumtree Run watershed.

The primary goal of this effort is to characterize baseline stream conditions (biological, physical habitat, and *in situ* chemical) prior to additional restoration project/BMP implementation. A secondary goal is to conduct monitoring in Plumtree Run that can be used to document ecological uplift and habitat improvement as projects are completed within this watershed.

1 Methods

The monitoring effort includes chemical (*in situ* water quality), physical (habitat assessment), and biological (benthic macroinvertebrate, fish, herpetofauna, freshwater mussels, and crayfish) assessments conducted at each of the selected sites. The sampling methods used are consistent with Maryland Department of Natural Resources' (DNR) Maryland Biological Stream Survey (MBSS). The methods have been developed locally and are calibrated specifically to Maryland's ecophysiographic regions and stream types.

1.1 Sampling Sites

Five sampling sites were selected within the Plumtree Run watershed (Figure 1) to characterize baseline stream conditions and to assess the effect of planned restoration on the ecological health of the watershed. A brief description of sites follows, for more detailed information about each site see the *Plumtree Run Monitoring Plan* (Harford County 2016).

1.1.1 Plum-1

Site Plum-1 is the downstream-most site in the Plumtree Run watershed. This site is located on the mainstem of Plumtree Run in the area of the USGS gage at Plumtree Road. This site will be used to measure overall watershed response to the restoration treatments implemented within the watershed. Since this site is located so close to the USGS gage on Plumtree Run, future analysis of the relationships between biological parameters, stream flow, and water quality may be possible. The land use upstream of Plum-1 is mostly urban and suburban (87.9%) with the remaining portion in agriculture (7.2%) and forest (4.8%). This site will integrate the effects of all future restoration projects in the watershed.

1.1.2 Plum-2

Plum-2 is located on the mainstem of Plumtree Run downstream of Tollgate Road within a previously completed stream restoration reach. The catchment upstream of this site is mostly urban and suburban land (90.4%) with the remaining land classified as agriculture (5.8%) and forest (3.8%). This site will measure ecological response to all restoration projects upstream of this point as those projects are implemented. This site will also directly measure habitat and ecological lift at the previously restored reach. This site is located approximately 420 meters downstream of a MBSS site (HA-P-151-10-96) sampled in 1996.

1.1.3 Plum-3

Plum-3 is located on the mainstem of Plumtree Run downstream of the political boundary of the Town of Bel Air. The upstream catchment to this site is mostly urban (93.5%) with the remaining land classified as agriculture (6.5%). This site will assess the ecological health of Plumtree Run as it enters Harford County's jurisdiction. It will also measure ecological response to future restoration as projects are implemented within the Town of Bel Air.

1.1.4 Plum-4

This site is located on an unnamed tributary to Plumtree Run, primarily draining urban (71.3%) land. The Plumtree Run plan identified extensive stream restoration and stormwater retrofit projects upstream of the site. This site will measure ecological lift possibly attributable to the planned restoration in this urbanized part of the Plumtree Run watershed. The benthic macroinvertebrate community at Plum-4 was sampled each of the five monitoring years, while the fish community was sampled only in Years 1 and 4.

1.1.5 Plum-5

This site is located on an unnamed tributary to Plumtree Run, primarily draining urban (98.7%) land. This site is downstream of two planned stream restoration projects and one stormwater BMP retrofit. This site will assess the ecological benefit of planned restoration in a heavily urbanized subwatershed. The benthic macroinvertebrate community at Plum-5 was sampled each of the five monitoring years, while the fish community was sampled only in Years 1 and 4.

1.2 Water Quality Sampling

Water quality conditions were measured *in situ* during the summer 2020 sampling visits at the three Plumtree Run sites. Currently the MBSS does not measure *in situ* water quality at sites, but did so in the past. *In situ* water quality methods used were consistent with those in DNR, 2010. Field measured parameters include temperature, dissolved oxygen, pH, specific conductance, and turbidity. Measurements at each site were made at the upstream end of the 75-meter long site. *In situ* measurements were made before any sampling activities started to avoid sampling water disturbed by other activities. Most *in situ* parameters (i.e., temperature, pH, specific conductivity, and dissolved oxygen) were measured using a multiparameter sonde (YSI Professional Plus), while turbidity was measured with a Hach 2100 Turbidimeter. Water quality meters are regularly inspected and maintained and were calibrated immediately prior to sampling to ensure proper usage and accuracy of the readings.

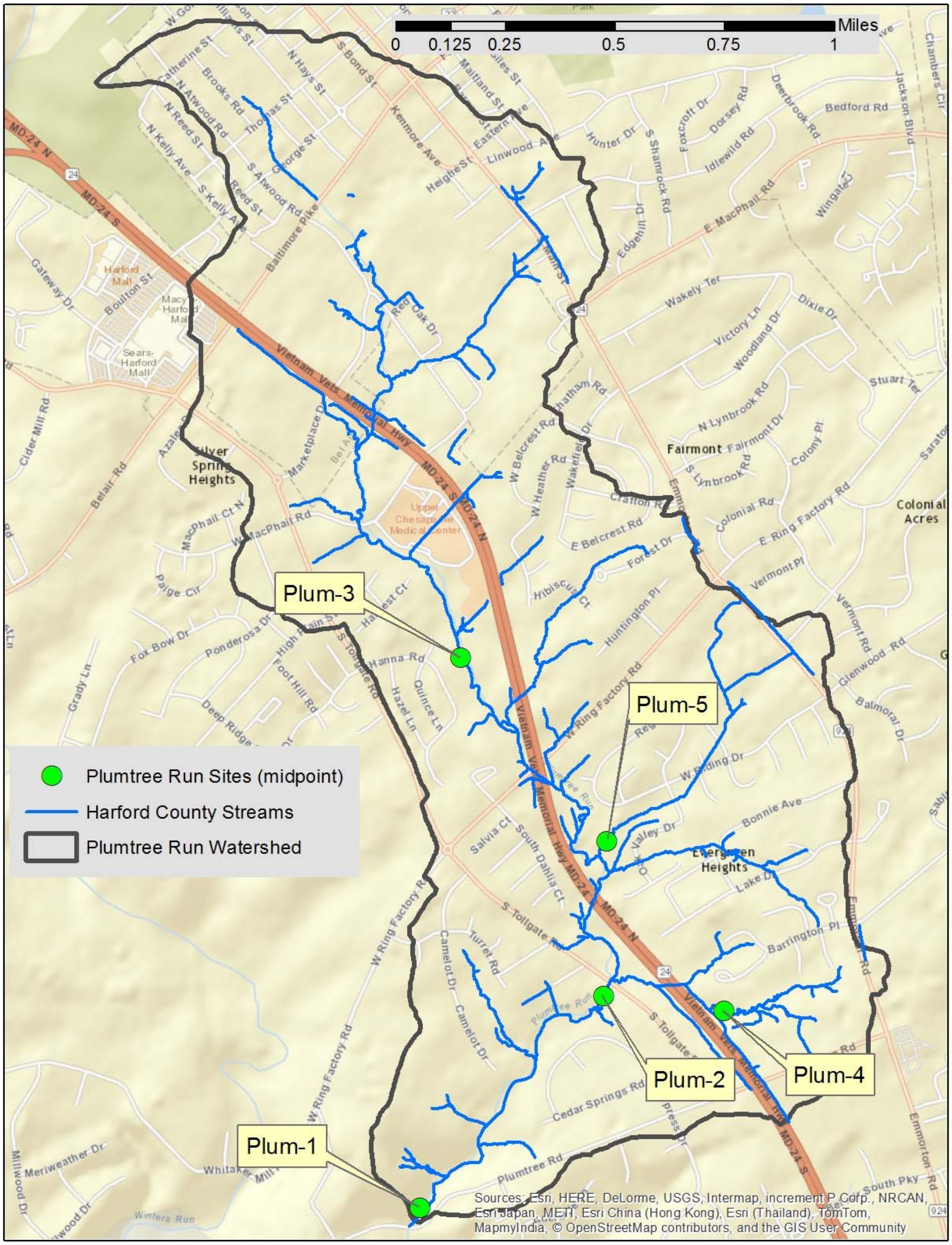

Figure 1 – Location of Sampling Sites

1.3 Physical Habitat Assessment

Each stream site was characterized based on visual observations of physical characteristics and various habitat parameters (Stranko et al. 2019). The Maryland Biological Stream Survey's (MBSS) Physical Habitat Index (PHI; Paul et al. 2002) was used to assess the physical habitat at the site.

To reduce individual sampler bias, assessments were completed as a team with discussion and agreement of the scoring for each parameter. In addition to the visual assessments, photographs were taken from three locations within each sampling reach (downstream end, midpoint, and upstream end) facing in the upstream and downstream direction, for a total of six (6) photographs per site.

The PHI incorporates the results of a series of habitat parameters selected for Coastal Plain, Piedmont and Highlands regions. While all parameters are rated during the field assessment, the Piedmont parameters were used to develop the PHI score for these sites because the Plumtree Run watershed is located in Maryland's Piedmont ecophysiographic region. In developing the PHI, MBSS identified eight parameters that have the most discriminatory power for the Piedmont streams. These parameters are used in calculating the PHI (Table 1). Several of the parameters have been found to be drainage area dependent and are scaled accordingly. The drainage area to each site was calculated in GIS using the GPS-collected location of each site, streams and 2-foot contour data from Harford County.

Table 1 – PHI Piedmont Parameters

Piedmont Stream Parameters	
Instream Habitat	Epifaunal Substrate
Bank Stability	Percent Shading
Remoteness	Number Woody Debris/Root wads

Each habitat parameter is given an assessment score ranging from 0-20, with the exception of shading (percentage 0-100%) and woody debris and root wads (total count). A prepared score and scaled score (0-100) are then calculated. The average of these scores yields the final PHI score. The final scores are then ranked according to the ranges shown in Table 2 and assigned corresponding narrative ratings, which allows for a score that can be compared to habitat assessments performed statewide.

Table 2 – PHI Score and Ratings

PHI Score	Narrative Rating
81.0 – 100.0	Minimally Degraded
66.0 – 80.9	Partially Degraded
51.0 – 65.9	Degraded
0.0 – 50.9	Severely Degraded

1.4 Benthic Macroinvertebrate Sampling

Benthic macroinvertebrate collection strictly followed MBSS procedures (Stranko et al. 2019). Sampling occurred during the Spring Index Period (March 1 – April 30), samples were collected from all five Plumtree Run sites on March 4, 2020. The monitoring sites consist of a 75-meter reach and benthic macroinvertebrate sampling is conducted once per year. The sampling methods utilize semi-quantitative field collections of the benthic macroinvertebrate community. The multi-habitat D-frame net approach is used to sample a range of the most productive habitat types present within the reach. Best available habitats include riffles, stable woody debris, root wads, root mats, leaf packs, aquatic macrophytes, and undercut banks. In this sampling approach, a total of twenty kicks or jabs (each approximately one square foot) are distributed proportionally among all best available habitats within the stream site and combined into a single composite sample and preserved in 95 percent ethanol. The composite sample contains material collected from approximately 20 square feet of habitat.

MBSS specifies that a minimum of 5% (1 in 20) of sites are selected for a duplicate sample (Stranko et al. 2019). Because the total number of samples in this project (5) is well below 20, Plumtree Run samples were pooled with other County monitoring project samples from Foster Branch (5) and Wheel Creek (4) to meet the field sampling QC objective (1 in 14, or 7.14%). The randomly selected QC site for 2020 was taken at Plum-2.

1.4.1 Benthic Macroinvertebrate Sample Processing and Laboratory Identification

Benthic macroinvertebrate samples were processed and subsampled according to methods described in the MBSS Laboratory Methods for Benthic Macroinvertebrate Processing and Taxonomy (Boward and Friedman 2019). Subsampling was conducted to standardize the sample size and reduce variation caused by samples of different size. In this method, the sample was spread evenly across a numbered, gridded tray (100 total grids), and a grid was picked at random and picked clean of organisms. If the organism count was 100 or more, then the subsampling was complete. If the organism count was less than 100, then another grid was selected at random and picked clean of organisms. This repeated until the organism count reached 100 to 120 organisms. The 100 (plus 20 percent) organism target is used to allow for specimens that are missing parts or are not mature enough for proper identification, are terrestrial, or meiofauna. Identification of the subsampled specimens was conducted by Environmental Services and Consulting, Inc. Taxa were identified to the genus level for most organisms. Groups including Oligochaeta and Nematomorpha were identified to the family level while Nematomorpha was left at phylum. Individuals of early instars or those that were damaged were identified to the lowest possible level, which could be phylum or order, but in most cases was family. Chironomidae could be further subsampled depending on the number of individuals in the sample and the numbers in each subfamily or tribe. Most taxa were identified using a stereoscope. Temporary slide mounts viewed with a compound microscope were used to identify Oligochaeta to family and for Chironomid sorting to subfamily and tribe. Permanent slide mounts were then used for Chironomid genus level identification. Results were logged on a bench sheet and entered into a spreadsheet for analysis.

Benthic macroinvertebrate lab quality control procedures followed those used by the MBSS (Boward and Friedman 2011). Because the total number of samples in this project (5) is well below 20, Plumtree Run samples were pooled with samples from Foster Branch (5) and Wheel Creek (4) to meet the laboratory QC objective (1 in 14, or 7.14%). The lab QC samples were selected at random from either Foster Branch, Wheel Creek or Plumtree Run samples. One (1) sample was randomly selected for QC re-identification by an independent lab.

1.4.2 Benthic Macroinvertebrate Data Analysis

Benthic macroinvertebrate data were analyzed by KCI using methods developed by MBSS as outlined in the *New Biological Indicators to Better Assess the Condition of Maryland Streams* (Southerland et al. 2005). The Benthic Index of Biotic Integrity (BIBI) approach involves statistical analysis using metrics that have a predictable response to water quality and/or habitat impairment. The metrics selected fall into five major groups including taxa richness, composition measures, tolerance to perturbation, trophic classification, and habit measures. Raw values from each metric were given a score of 1, 3 or 5 based on ranges of values developed for each metric. The results were combined into a scaled IBI score from 1.00 to 5.00, and a corresponding narrative biological condition rating was applied.

Three sets of metric calculations have been developed for Maryland streams based on broad eco-physiographic regions. These include the Coastal Plain, Piedmont and combined Highlands. The study area is located in the Piedmont region therefore the following metrics (Table 3) and IBI scoring (Table 4) were used for the analysis.

Table 3 – Benthic Macroinvertebrate Metric Scoring for the Piedmont BIBI

Metric	Score		
	5	3	1
Total Number of Taxa	≥ 25	15 – 24	< 15
Number of EPT Taxa	≥ 11	5 – 10	< 5
Number of Ephemeroptera Taxa	≥ 4	2 – 3	< 2
% Intolerant to Urban	≥ 51	12 – 50	< 12
% Chironomidae	≤ 24	24 – 63	> 63
% Clingers	≥ 74	31 – 73	< 31

*Adjusted for catchment size

Table 4 – BIBI Condition Ratings

IBI Score	Narrative Rating
4.00 – 5.00	Good
3.00 – 3.99	Fair
2.00 – 2.99	Poor
1.00 – 1.99	Very Poor

1.5 Fish Sampling

The fish community at the three visited Plumtree Run sites was sampled during the Summer Index Period, June 1 through September 30, according to methods described in *Maryland Biological Stream Survey: Round Four Field Sampling Manual* (Stranko et al. 2019). In general, the approach uses two-pass electrofishing of the entire 75-meter study reach. Block nets were placed at the upstream and downstream ends of the reach, as well as at tributaries or outfall channels, to obstruct fish movement into or out of the study reach. Two passes were completed along the reach to ensure the segment was adequately sampled. The time in seconds for each pass was recorded and the level of effort for each pass was similar. Captured fish were identified to species and enumerated following MBSS protocols (Stranko et al. 2019). A total fish biomass for each electrofishing pass was measured. Unusual anomalies such as fin erosion, tumors, etc. were recorded. Photographic vouchers were taken in lieu of voucher specimens.

1.5.1 Fish Data Analysis

Fish data for Plumtree Run sites were analyzed using methods developed by MBSS as outlined in the *New Biological Indicators to Better Assess the Condition of Maryland Streams* (Southerland et al. 2005). The IBI approach involves statistical analysis using metrics that have a predictable response to water quality and/or habitat impairment. Raw values from each metric were assigned a score of 1, 3 or 5 based on ranges of values developed for each metric. The results were combined into a scaled FIBI score, ranging from 1.0 to 5.0, and a corresponding narrative rating of ‘Good’, ‘Fair’, ‘Poor’ or ‘Very Poor’ was applied, again in accordance with standard practice.

Four sets of FIBI metric calculations have been developed for Maryland streams. These include the Coastal Plain, Eastern Piedmont, and warmwater and coldwater Highlands. Plumtree Run is located in the Eastern Piedmont region, therefore, the following metrics listed in Table 5 were used for the FIBI scoring (Table 6) and analysis.

Table 5 – Fish Metric Scoring for the Piedmont FIBI

Metric	Score		
	5	3	1
Abundance per Square Meter	≥ 1.25	0.25 – 1.24	< 0.25
Number of Benthic species *	≥ 0.26	0.09 – 0.25	< 0.09
% Tolerant	≤ 45	46 – 68	> 68
% Generalist, Omnivores, Invertivores	≤ 80	81 – 99	100
Biomass per Square Meter	≥ 8.6	4.0 – 8.5	< 4.0
% Lithophilic Spawners	≥ 61	32 – 60	< 32

*Adjusted for catchment size

Table 6 – FIBI Condition Ratings

IBI Score	Narrative Rating
4.00 – 5.00	Good
3.00 – 3.99	Fair
2.00 – 2.99	Poor
1.00 – 1.99	Very Poor

1.6 Herpetofauna Survey

Herpetofauna (i.e., reptiles and amphibians) were surveyed at each of the five Plumtree Run sites using methods following MBSS protocols (Stranko et al. 2019). All collected individuals were identified to species level and released. Photographic vouchers were collected if a specimen could not be positively identified in the field.

Herpetofauna data collection occurs primarily to assist MBSS with supplementing their inventory of biodiversity in Maryland’s streams. Currently, MBSS has not developed any indexes of biotic integrity for herpetofauna, and therefore, they were not used to evaluate the biological integrity of sampling sites throughout this study. Rather, the data are provided to help document existing conditions.

1.7 Freshwater Mussel Survey

A survey of freshwater mussels was conducted at each site using MBSS protocols (Stranko et al. 2019). A search for freshwater mussels was conducted at each site. Any live individuals encountered were identified, photographed, and then returned back to the stream as closely as possible to where they were collected. Any dead shells were retained as voucher specimens.

1.8 Crayfish Survey

Crayfish were surveyed for at each sampling site using MBSS protocols (Stranko et al. 2019). All crayfish observed while electrofishing were captured and retained until the end of each electrofishing pass. Captured crayfish were identified to species and counted before release back into the stream outside of the 75-meter sampling reach. Any crayfish encountered outside of the electrofishing effort were identified and noted on the datasheet as an incidental observation. Any crayfish burrows observed in and around the sampling site were excavated and an attempt made to capture the burrowing crayfish.

1.9 Invasive Plant Survey

A survey of invasive plants was performed at each sampling site during the Summer Index Period following MBSS protocols (Stranko et al. 2019). The common name and relative abundance of invasive plants (i.e., present or extensive) within view of the study reach and within the 5-meter riparian vegetative zone parallel the stream channel were recorded.

Invasive plant data collection occurs to assist MBSS with supplementing their inventory of biodiversity. The data are provided to help document existing conditions at each site.

1.10 Quality Assurance and Quality Control

All work was conducted with thorough quality assurance and quality control. Biological assessment methods have been designed to be consistent and comparable with the methods used by MBSS (Stranko et al. 2019). Field crews receive yearly training in MBSS protocols and certification by DNR to perform benthic macroinvertebrate and fish sampling procedures. All field forms are checked and signed by the Crew Leader before leaving the site. Digital data entry is also checked for accuracy. Field equipment are checked regularly and calibrated as necessary prior to use. Calculation of metric scores and IBIs are completed using KCI's controlled and verified spreadsheet and each site undergoes a documented quality control check.

2 Results and Discussion

Biological monitoring and water quality sampling were conducted to assess the conditions in the Plumtree Run watershed. Presented below are the summary results for each monitoring component.

2.1 Water Quality

Water quality measurements were collected during the Summer Index Period sampling visit during all five years at the three Plumtree Run sites. Table 7 presents the results of the *in situ* water quality measurements.

Table 7 – In Situ Water Quality Measurement Results

Site	Season	Temperature (°C)	Dissolved Oxygen (mg/L)	pH (Units)	Specific Conductance (µS/cm)	Turbidity (NTU)
Plum-1	Summer 2015	15.1	9.92	7.52	596.7	0.89
Plum-1	Summer 2016	19.4	9.01	7.41	332.2	2.23
Plum-1	Summer 2017	21.0	8.75	7.82	436.9	7.89
Plum-1	Summer 2019	20.7	7.77	7.69	514.6	2.05
Plum-1	Summer 2020	23.0	8.10	7.63	623.0	2.01
Plum-2	Summer 2015	17.6	9.94	7.22	672.0	4.95
Plum-2	Summer 2016	21.7	7.41	6.98	357.9	3.67
Plum-2	Summer 2017	23.2	7.14	8.98	482.8	8.93
Plum-2	Summer 2019	22.9	8.22	7.08	599.0	4.99
Plum-2	Summer 2020	25.8	7.14	7.45	708.0	2.58
Plum-3	Summer 2015	16.5	8.54	7.18	887.0	1.72
Plum-3	Summer 2016	22.6	8.36	6.92	726.0	1.30
Plum-3	Summer 2017	22.0	6.41	7.22	589.0	5.08
Plum-3	Summer 2019	24.4	8.03	7.13	937.0	1.38
Plum-3	Summer 2020	20.2	7.81	7.35	905.0	2.63
Plum-4	Summer 2015	15.4	7.01	6.81	384.2	1.13
Plum-4	Summer 2019	14	9.73	6.99	446.4	1.33
Plum-5	Summer 2015	17.8	7.22	7.12	433.9	1.40
Plum-5	Summer 2019	17.7	9.51	7.26	417.7	1.61

Shaded cells indicate values exceeding either water quality criteria or published values

MDE has established acceptable water quality standards for each designated Stream Use Classification, which are listed in the *Code of Maryland Regulations (COMAR) 26.08.02.03-.03 - Water Quality*. Plumtree Run is covered in *COMAR* in Sub-Basin 02-13-07: Bush River Area as Use IV-P waters. Specific designated uses for Use IV-P streams include public water supply, supporting adult trout for put-and-take fishing, growth and propagation of fish and aquatic life, water supply for industrial and agricultural use, water contact sports, fishing, and leisure activities involving direct water contact.

The acceptable criteria for Use IV-P waters are as follows:

- pH - 6.5 to 8.5
- DO - may not be less than 5 mg/l at any time
- Turbidity - maximum of 150 Nephelometric Turbidity Units (NTU's) and maximum monthly average of 50 NTU
- Temperature - maximum of 75°F (23.9°C) or ambient temperature of the surface water, whichever is greater

In situ water quality measurements for temperature, dissolved oxygen, and turbidity were within COMAR standards for Use IV-P streams. At Plum-2 during Year 3/Summer of 2017 the pH was 8.98, exceeding the COMAR criteria. All other pH values fell within the criteria. Although MDE does not have a water quality standard for specific conductivity, Morgan and others (Morgan et al, 2007; Morgan et al, 2012) have reported critical values for specific conductance in Maryland streams, above which there is a potential for detrimental effects on the stream biological communities. For the benthic macroinvertebrate community that critical value is 247 µS/cm, and for the fish community it is 171 µS/cm. Each of the Plumtree Run stream sites had specific conductivity values far exceeding the threshold for both benthic macroinvertebrate and fish community impairments for all water quality sampling events. Conductivity levels in this watershed are likely influenced by runoff from impervious surfaces (i.e., roads, sidewalks, parking lots, roof tops). Increased stream inorganic ion concentrations (i.e., conductivity) in urban systems typically results from paved surface de-icing, accumulations in storm-water management facilities (Casey et al. 2013), runoff over impervious surfaces, passage through pipes, and exposure to other infrastructure (Cushman 2006). While elevated conductivity may not directly affect stream biota, its constituents (e.g., chloride, metals, and nutrients) may be present at levels that can cause biological impairment.

2.2 Physical Habitat Assessment

The summary results of the PHI habitat assessments for Years 1, 2, 3, 4, and 5 are presented in Table 8. All Plumtree Run sites have compromised physical habitat, with PHI ratings of 'Degraded' for all sites in Year 1 and all sites in Year 2 except Plum-1. Plum-1 had the best habitat scores of the five sites with a 'Partially Degraded' in Year 2. Year 3 had the same results as Year 2 with Plum-1 receiving a rating of 'Partially Degraded' while the other sites both received ratings of 'Degraded'. Year 4 had similar results with all sites scoring as 'Degraded' except Plum-4 which received a rating of 'Partially Degraded'. Year 5 results remained the same at Plum-2 while Plum-1 received a rating of 'Partially Degraded' and Plum-3 received a rating of 'Severely Degraded'. The relatively low habitat scores are likely due to urbanization effects on streams. Complete physical habitat data for each site are included in Appendix A.

Table 8 – RBP and PHI Habitat Assessment Results

Site	Season	PHI Score	PHI Narrative Rating
Plum-1	Summer 2015	64.6	Degraded
Plum-1	Summer 2016	71.2	Partially Degraded
Plum-1	Summer 2017	66.4	Partially Degraded
Plum-1	Summer 2019	58.3	Degraded
Plum-1	Summer 2020	70.0	Partially Degraded
Plum-2	Summer 2015	54.0	Degraded
Plum-2	Summer 2016	58.5	Degraded
Plum-2	Summer 2017	58.2	Degraded
Plum-2	Summer 2019	51.3	Degraded
Plum-2	Summer 2020	54.4	Degraded
Plum-3	Summer 2015	59.0	Degraded
Plum-3	Summer 2016	64.1	Degraded
Plum-3	Summer 2017	60.4	Degraded
Plum-3	Summer 2019	54.1	Degraded
Plum-3	Summer 2020	42.2	Severely Degraded
Plum-4	Summer 2015	59.5	Degraded
Plum-4	Summer 2019	69.0	Partially Degraded
Plum-5	Summer 2015	54.2	Degraded
Plum-5	Summer 2019	52.1	Degraded

2.3 Benthic Macroinvertebrate Community

The results of Year 5 benthic macroinvertebrate community assessments are presented in Table 9. Complete benthic macroinvertebrate data for each site are included in Appendix B.

Table 9 – Benthic Index of Biotic Integrity (BIBI) Summary Data – Year 5

Metric	Plum-1	Plum-2	Plum-3	Plum-4	Plum-5	Plum-2 QC
Metric Values						
Total Number of Taxa	16	18	16	14	20	15
Number of EPT Taxa	4	4	3	4	4	4
Number of Ephemeroptera Taxa	0	0	0	0	0	0
% Intolerant to Urban	2.44	0.00	0.00	19.20	0.75	2.36
% Chironomidae	82	81.36	72.44	74.40	87.31	74.02
% Clingers	2.44	15.25	37.80	24.00	17.16	27.56
Metric Scores						
Total Number of Taxa	3	3	3	1	3	3
Number of EPT Taxa	1	1	1	1	1	1
Number of Ephemeroptera Taxa	1	1	1	1	1	1
% Intolerant to Urban	1	1	1	3	1	1
% Chironomidae	1	1	1	1	1	1
% Clingers	1	1	3	1	1	1
BIBI Score	***1.33***	***1.33***	***1.67***	***1.33***	***1.33***	***1.33***
Narrative Rating	**Very Poor**	**Very Poor**	**Very Poor**	**Very Poor**	**Very Poor**	***Very Poor***

For Year 5 benthic macroinvertebrate sampling, all five Plumtree Run sites had BIBI ratings in the 'Very Poor' category, with Plum-1, Plum-2, Plum-4, and Plum-5 scoring 1.33, the lowest scores.
The individual metrics scored consistently low across all sites with none of the site receiving a score of 5 for any metrics. Two metrics, Number of EPT Taxa and Number of Ephemeroptera Taxa scored consistently low across all five sites with each site scoring the lowest possible '1' for these two metrics. Minor differences in the other four metrics (Total Number of Taxa, Percent Chironomidae, Percent Intolerant to Urban, and Percent Clingers) accounted for the variation in BIBI scores. These low BIBI scores are possibly due to poor habitat and water quality. All sites had measured specific conductivity values greater than the published impairment threshold for benthic macroinvertebrates.

The QC sample from Plum-2 scored the same as the non-QC sample, in the 'Very Poor' category. There were minor differences in some metrics but those differences were not enough to result in a change in metric scoring.

A comparison of BIBI scores across the five years of monitoring is presented in Table 10 and Figure 2.

Three of the five Plumtree Run sites had BIBI scores that were lower in Year 5 than in Year 4 (Plum-1, Plum-2, and Plum-5), while Plum-3 and Plum-4 remained the same between years. Sites Plum-1, Plum-2 and Plum-5 had the largest BIBI score difference (-0.67), scoring a 2.00 in Year 4 and a 1.33 in Year 5. Sites Plum-3 and Plum-4 had no change between years.

Table 10 – BIBI Scores and Narrative Rating for all Years

Site	Year	BIBI Score	Narrative Rating
Plum-1	1 (Spring 2016)	2.67	Poor
Plum-1	2 (Spring 2017)	1.00	Very Poor
Plum-1	3 (Spring 2018)	1.33	Very Poor
Plum-1	4 (Spring 2019)	2.00	Poor
Plum-1	5 (Spring 2020)	1.33	Very Poor
Plum-2	1 (Spring 2016)	2.00	Poor
Plum-2	2 (Spring 2017)	1.00	Very Poor
Plum-2	3 (Spring 2018)	1.33	Very Poor
Plum-2	4 (Spring 2019)	2.00	Poor
Plum-2	5 (Spring 2020)	1.33	Very Poor
Plum-3	1 (Spring 2016)	2.00	Poor
Plum-3	2 (Spring 2017)	1.33	Very Poor
Plum-3	3 (Spring 2018)	1.67	Very Poor
Plum-3	4 (Spring 2019)	1.67	Very Poor
Plum-3	5 (Spring 2020)	1.67	Very Poor
Plum-4	1 (Spring 2016)	2.33	Poor
Plum-4	2 (Spring 2017)	2.00	Poor
Plum-4	3 (Spring 2018)	1.00	Very Poor
Plum-4	4 (Spring 2019)	1.33	Very Poor
Plum-4	5 (Spring 2020)	1.33	Very Poor
Plum-5	1 (Spring 2016)	2.00	Poor
Plum-5	2 (Spring 2017)	1.67	Very Poor
Plum-5	3 (Spring 2018)	1.67	Very Poor
Plum-5	4 (Spring 2019)	2.00	Poor
Plum-5	5 (Spring 2020)	1.33	Very Poor

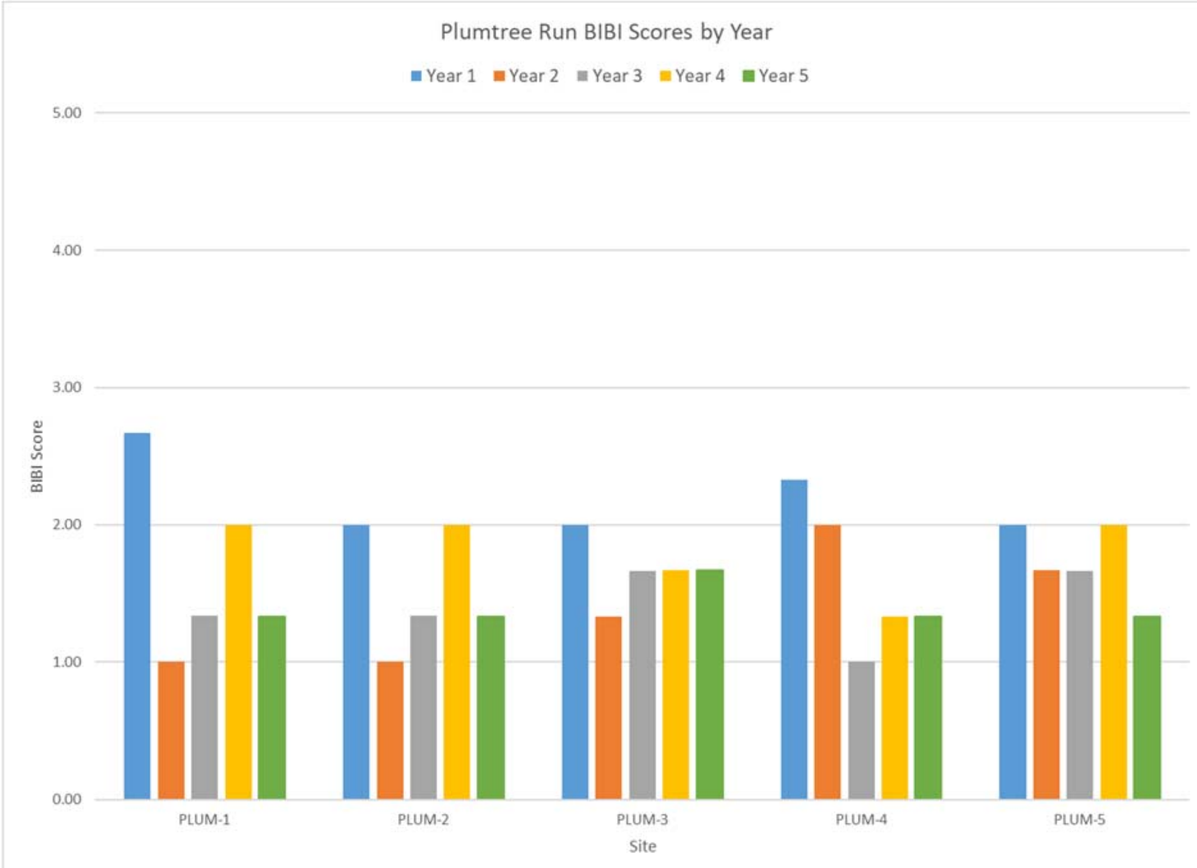

Figure 2 – BIBI Scores by Year

2.4 Fish Community

The results of the Year 5 fish community assessments are presented in Table 11 and a list of species collected over all five sampling years at each site can be found in Table 12. Complete fish community data for each site are included in Appendix C.

The Plumtree Run sites had FIBI ratings ranging from 'Poor' to 'Good'. Sites Plum-4 and Plum-5 were only sampled in Year 1 and Year 4 as per the Plumtree Run Monitoring Plan. These two sites are sufficiently small enough in contributing drainage area (each approx. 100 acres) that a Maryland-specific species-area curve suggests that very few, if any, fish species are expected to be observed; therefore fish community may not be a useful indicator of stream condition.

Table 11 – Fish Index of Biotic Integrity (FIBI) Summary Data – Year 5

Metric	Plum-1	Plum-2	Plum-3
Metric Values			
Abundance per Square Meter	1.66	5.19	2.82
Adjusted Number of Benthic Species	1.23	0.65	0.84
% Tolerant	57.61%	74.53%	78.52%
% Generalist, Omnivores, Invertivores	69.57%	88.50%	92.35%

Biomass per Square Meter	3.77	19.23	6.08
% Lithophilic Spawners	59.56%	30.79%	52.22%
Metric Scores			
Abundance per Square Meter	5	5	5
Adjusted Number of Benthic Species	5	5	5
% Tolerant	3	1	1
% Generalist, Omnivores, Invertivores	5	3	3
Biomass per Square Meter	1	5	3
% Lithophilic Spawners	3	1	3
FIBI Score	***3.67***	***3.33***	***3.33***
Narrative Rating	***Fair***	***Fair***	***Fair***

Table 12 – Cumulative List of Fish Species Collected at Plumtree Run Sites

Common Name	Scientific Name	Plum-1	Plum-2	Plum-3	Plum-4	Plum-5
White Sucker	*Catostomus commersonii*	X	X	X		
Bluntnose Minnow	*Pimephales notatus*	X	X	X		
Fathead Minnow	*Pimephales promelas*	X	X	X		
Cutlip Minnow	*Exoglossum maxillingua*		X			
Satinfin Shiner	*Cyprinella analostana*		X	X		
Common Shiner	*Luxilus cornutus*	X	X			
Rosyside Dace	*Clinostomus funduloides*	X	X	X		X
Creek Chub	*Semotilus atromaculatus*	X	X	X	X	X
Fallfish	*Semotilus corporalis*	X	X			
Blacknose Dace	*Rhinichthys atratulus*	X	X	X	X	X
Longnose Dace	*Rhinichthys cataractae*	X	X	X	X	X
Eastern Mosquitofish	*Gambusia holbrooki*		X			
Blue Ridge Sculpin	*Cottus caeruleomentum*	X	X	X		X
Brown Bullhead	*Ameiurus nebulosus*		X			
Tessellated Darter	*Etheostoma olmstedi*	X	X			
Largemouth Bass	*Mictopterus salmoides*		X			
Redbreast Sunfish	*Lepomis auritus*	X	X	X		
Bluegill	*Lepomis macrochirus*		X	X		
Pumplkinseed	*Lepomis gibbosus*		X			
Green Sunfish	*Lepomis cyanellus*			X		
Hybrid Sunfish	*Lepomis sp.*		X			

Site Plum-1 had the highest FIBI score, 3.67 which rated ‘Fair’. Sites Plum-2 and Plum-3 also received a rating of ‘Fair’, with both scores being 3.33. Ten species of fish have been collected at Plum-1, ten species collected at Plum-3 and 17 species collected at Plum-2 (the restored site) which had the highest diversity of the three sites. Metrics for Adjusted Number of Benthic Species, and Abundance per Square Meter were consistent between the three sites. Biomass per Square Meter varied the most between the sites, with Plum-2 scoring a ‘5’, Plum-scoring a ‘3’, and Plum-1 scoring a ‘1’. Minor differences in the other three metrics between sites accounted for the minor variability in FIBI scores between sites

A comparison of FIBI scores across the five years of monitoring is presented in Table 13 and Figure 3. Overall, FIBI scores at the three Plumtree Run sites monitoring in the five years varied slightly. Plum-3 scored a 3.33 all five years, Plum-1 had a slightly lower FIBI score (-0.33) in Year 2, but then increased to 4.00 in Year 3 and remained at 4.00 in Year 4 but then lowered again (-0.33) in Year 5. Plum-2 had a slightly higher FIBI score of 4.00 in Year 2, but then has remained in the 'Fair' rating in Years 3, 4, and 5 (3.33, 3.67, 3.33 respectively). Plum-4 remained the same with a 'Poor' rating in both Year 1 and Year 4 while Plum-5 increased to 'Fair' in Year 4 from a rating of 'Poor' in Year 1.

Table 13 – FIBI Scores and Narrative Rating Across Years

Site	Year	FIBI Score	Narrative Rating
Plum-1	1 (Summer 2015)	3.67	Fair
Plum-1	2 (Summer 2016)	3.33	Fair
Plum-1	3 (Summer 2017)	4.00	Good
Plum-1	4 (Summer 2019)	4.00	Good
Plum-1	5 (Summer 2020)	3.67	Fair
Plum-2	1 (Summer 2015)	3.67	Fair
Plum-2	2 (Summer 2016)	4.00	Good
Plum-2	3 (Summer 2017)	3.33	Fair
Plum-2	4 (Summer 2019)	3.67	Fair
Plum-2	5 (Summer 2020)	3.33	Fair
Plum-3	1 (Summer 2015)	3.33	Fair
Plum-3	2 (Summer 2016)	3.33	Fair
Plum-3	3 (Summer 2017)	3.33	Fair
Plum-3	4 (Summer 2019)	3.33	Fair
Plum-3	5 (Summer 2020)	3.33	Fair
Plum-4	1 (Summer 2015)	2.67	Poor
Plum-4	4 (Summer 2019)	2.67	Poor
Plum-5	1 (Summer 2015)	2.67	Poor
Plum-5	4 (Summer 2019)	3.00	Fair

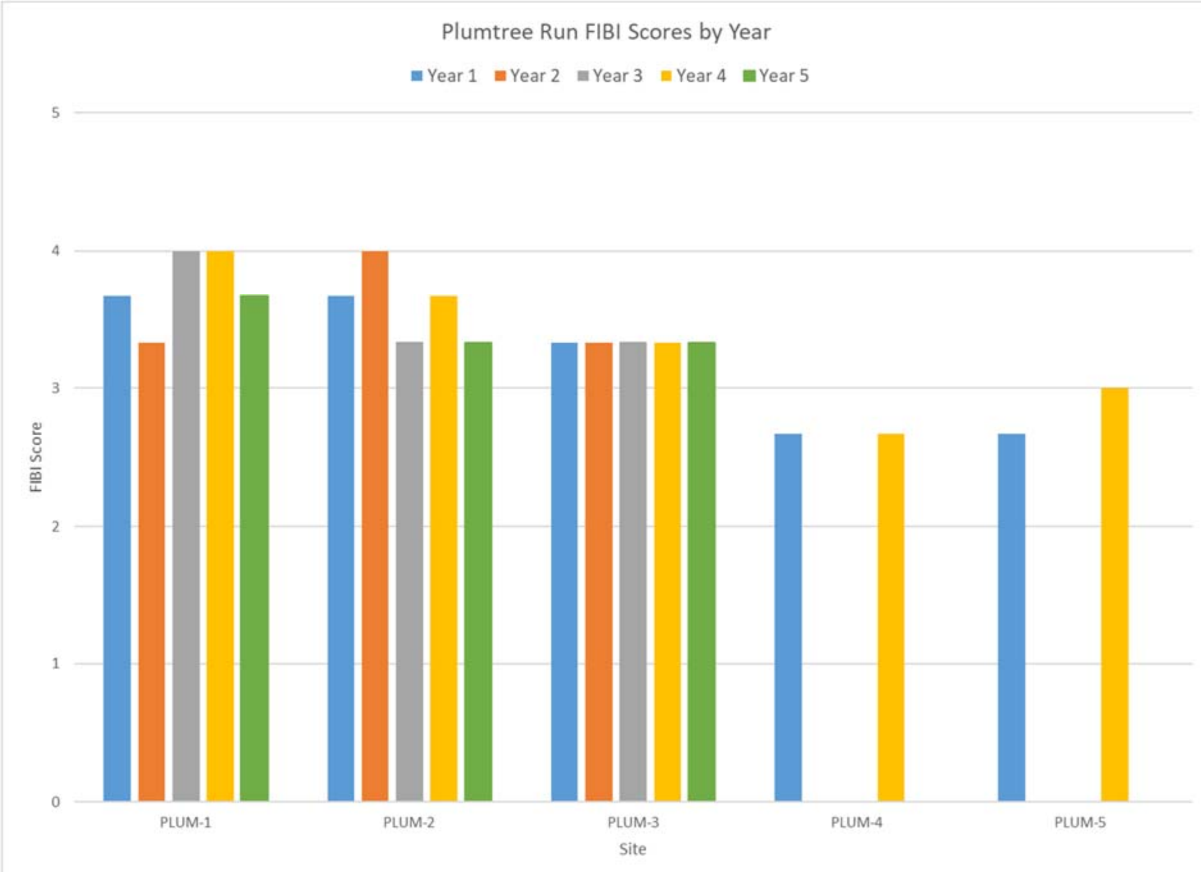

Figure 3 – FIBI Scores by Year

2.5 Herpetofauna

At least two reptile or amphibian species were collected at each of the sites, as presented in Table 14 which represents all species found at each monitoring site across all sampling visits. Plum-2 had the highest diversity with five species present at the site. The most widely distributed species was Northern Two-lined Salamander, which was present at each of the five Plumtree Run sites. Numbers of stream salamander individuals were low at all sites where they were observed; one or two Northern Two-lined Salamander individuals were observed at most sites, Plum-4 and Plum-5 had the greatest stream salamander diversity with both Northern Two-lined Salamanders and Northern Dusky observed during summer of 2019

Table 14 – Cumulative Herpetofauna Presence at Plumtree Run Sites

Common Name	Scientific Name	Plum-1	Plum-2	Plum-3	Plum-4	Plum-5
American Toad	*Anaxyrus americanus*	X		X		
Northern Green Frog	*Lithobates clamitans melanota*	X	X	X	X	X
Northern Spring Peeper	*Pseudacris crucifer*		X			
Northern Watersnake	*Nerodia sipedon sipedon*	X	X			
Stream Salamanders						
Northern Dusky Salamander	*Desmognathus fuscus*				X	X

Common Name	Scientific Name	Plum-1	Plum-2	Plum-3	Plum-4	Plum-5
Northern Two-lined Salamander	*Eurycea bislineata*	X	X	X	X	X

The low density of stream salamanders at all sites is likely due to a combination of habitat degradation and water quality impairment. There was very little suitable stream salamander habitat present at Plum-2 during all five years for the field crew to search. Stream salamanders generally prefer large cover objects over loose cobble and gravel, creating a moist microclimate and many interstices for shelter and foraging. The restoration reach (Plum-2) contained several areas of armored banks and rock structures in the stream. Water quality may be influencing the distribution of stream salamanders in the Plumtree Run watershed. Measured specific conductivity was high at all five sites, ranging from 332 to 937 µS/cm. Stream salamanders breathe through their skins, and because of their highly permeable skin are particularly sensitive to water quality impairments. The high conductivity values suggest that salamanders would experience osmotic difficulties in these conditions.

2.6 Freshwater Mussels

No freshwater mussels were observed at any Plumtree Run site during the five years of monitoring. The lack of freshwater mussels at these sites is likely due to a combination of habitat degradation and water quality impairment. Freshwater mussels are relatively sessile organisms which live partially embedded within the stream substrates. The flashy hydrology characteristic of urban streams like Plumtree Run create habitat conditions unsuitable for freshwater mussels. Also, it is likely that water quality conditions in urban streams are outside the range of tolerance of these sensitive organisms.

2.7 Crayfish

Crayfish were observed at all Plumtree Run sites. *Faxonius virilis*, a non-native species, was the only crayfish species observed at these sites. *F. virilis* was observed during electrofishing in Year 1, Year 2, Year 3, Year 4, and Year 5 sampling efforts at all sites. Crayfish burrows were not observed at any of the Plumtree Run sites. The lack of native crayfish is most likely due to competition with non-native crayfish. In the Patapsco River watershed, *Faxonius virilis* has displaced the native *Faxonius limosus* from the entire watershed (Kilian et al. 2010). It is likely that a similar species displacement has occurred in the Winters Run watershed. Water quality conditions may also be impacting crayfish, but currently the water quality requirements for crayfish in Maryland are poorly understood.

2.8 Invasive Plant Species

Invasive plant species were present at each of the Plumtree Run sites. Table 15 presents all invasive species found at each monitoring site across all sampling visits. Plum-2 has the most invasive plant species with 13, and Plum-4 had the least with four. Japanese stiltgrass and Mulitflora rose were the most widely distributed invasive plant, each found at all five sites.

Table 15 – Cumulative Invasive Plant Species Presence at Plumtree Run Sites

Common Name	Scientific Name	Plum-1	Plum-2	Plum-3	Plum-4	Plum-5
Garlic Mustard	*Allaria petiolata*	X	X			X
Common ragweed	*Ambrosia artemisiifolia*		X			X
Japanese barberry	*Berberis thunbergii*	X		X	X	
Oriental bittersweet	*Celastrus orbiculatus*	X	X	X		X
Fireweed	*Chamerion angustifolium*			X		

Autumn Clematis	*Clematis terniflora*	X	X	X		
Ground ivy	*Glechoma hederacea*		X			
English ivy	*Hedera helix*	X	X	X		
Chinese Lespedeza	*Lespedeza cuneata*		X			
Privet	*Ligustrum sp.*			X		
Japanese honeysuckle	*Lonicera japonica*	X		X		X
Japanese stiltgrass	*Microstegium vimineum*	X	X	X	X	X
Mile-a-minute	*Persicaria perfoilata*		X	X		X
Mimosa tree	*Albizia julibrissin*		X			
Multiflora rose	*Rosa multiflora*	X	X	X	X	X
Wineberry	*Rubus phoenicolasius*		X	X	X	X
Vinca vine	*Vinca sp.*		X			

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PCB monitoring and source tracking in the Bush River watershed

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Background and Objectives

Bush River was identified by the Maryland Department of Environment (MDE) as impaired for Polychlorinated biphenyls (PCB) in fish tissue (MDE 2002). In 2016 the USEPA approved a Total Maximum Daily Load (TMDL) of PCB in the Bush River Oligohaline Segment (Harford County, MD), referred as "Bush River" in this document.

To develop the TMDL and assess sources of contamination, MDE collected and analyzed fish tissue, measured concentration in sediments from Bush River, and conducted PCB monitoring in the water column with 4 discrete sampling events between 2013 and 2014 for 6 tidal and 4 non tidal locations. They did not include resuspension and diffusion from bottom sediment of Bush River since they are considered as internal loading. Majority of the loading (65.8%) was attributed to non point sources, including Maryland non-regulated watershed run off (40.6%), direct atmospheric deposition (24%) and contaminated sites (1.2%). Point sources loading represented 34.2% of the total and comprised National Pollutant Discharge Eliminations System (NPDES) for regulated stormwater (24.4%) and for regulated municipal Waste Water Treatment Plants (9.8%).

The Harford County and the Maryland Department of Environment (MDE) would like to pursue the monitoring and assess ongoing contribution of polychlorinated biphenyls (PCBs) from several streams in the Bush River watershed. Notably, Harford County proposes to "provide additional monitoring to better quantify the extent of PCB loads prior to investing large quantities of funding for capital improvements projects". Harford County identified several locations for further investigation, with an initial focus on Bynum watershed that exhibited one of the highest non-regulated watershed run-off.

Proposed work

We propose a systematic study of the water column PCB concentrations in the Bush River and selected tributaries with the goal of tracking potential ongoing sources of contamination that impacts water quality. The monitoring will follow recent work performed by UMBC to track ongoing sources in the Anacostia River (Ghosh et al. 2019). The focus here will be the dissolved concentration load during baseflow that has the most impact on the water quality as demonstrated in our earlier work in the Anacostia River. PCB concentrations in storm water and in sediments carried during storms are extremely low due to dilution and does not cause negative impacts on water quality and uptake in organisms. Monitoring dissolved concentration loads during baseflow should be able to determine the major ongoing inputs to the Bush River that has negative impact in terms of bioaccumulation in the food chain.

The monitoring will include focused measurements of the following:

1) <u>Freely dissolved PCBs at selected locations</u>. The freely dissolved concentrations of PCBs in surface water and sediment porewater will be measured using an integrative passive sampling approach. This sampling approach allows measurement of average concentrations of the freely dissolved PCBs in surface water that serve as the driving force for uptake in fish. In addition to being indicative of biological uptake, toxicity, and pollutants flux between sediments and water column (USEPA 2012a,b; Fernandez et al 2009), the freely dissolved concentrations can be used to identify potential sources or hot spots of PCB release in a watershed. Direct measurement of sparingly soluble chemicals like PCBs in the water phase is challenging due to the ultra-low aqueous concentrations and interference with colloidal particles. Passive sampling has emerged as an alternative technique to assess freely dissolved concentrations of hydrophobic chemicals without interference from colloidal particles (USEPA 2012b; Ghosh et al. 2014). Besides, passive sampling yields an average concentration that is representative of pollutant concentration during base flow and episodic rainfall events during the deployment time of the passive samplers.

2) <u>Water quality parameters and discharge</u>. In addition to PCB concentrations, periodic sampling of suspended solids, organic carbon content of the suspended solids, and dissolved organic carbon measurements will be performed. These additional measurements will allow calculation of total PCB loads from each of the tributaries. The discharge from each of the tributaries will be assessed based on catchment area delineation as done in the existing TMDL for Bush River.

3) <u>Selected sampling and measurement of PCB concentration in sediments</u>. At each of the water sampling points described below, co-located samples of sediment will be collected for PCB analysis. Results of PCBs in deposit sediments in the Bush river will be compared with PCB concentration in sediments currently coming form each of the tributaries. This comparison will allow an assessment of whether the ongoing sediment inputs are resulting in contamination of the river bed or helping clean up the legacy sediments in the river. This is a critical piece of assessment that will allow for the determination of whether controlling ongoing sediment inputs will be helpful in reducing PCB impacts in the river. Note that in our recent tributary study for Anacostia River, we found that PCB concentration in suspended sediments are extremely low (at least by an order of magnitude) compared to suspended sediments during baseflow (Ghosh et al. 2019). In the past, there has been a major focus on storm sediments based on the high volume of sediments mobilized during a storm. However, from the perspective of PCB loading with impact on water quality, storm sediments are irrelevant due to the extremely low concentrations. In fact, sediments with ultra-low concentrations of PCBs mobilized during storms from the tributaries lead to deposition of clean sediments in the river and is beneficial.

4) Limited air sampling for PCBs. Finally, to get an estimate of atmospheric loading, UMBC also proposes the deployment of two air passive samplers to measure PCB concentration in the air in the local region. PCB air concentration in combination with data from water column monitoring will be used to estimate the air-water exchange flux of PCBs in the Bush River. This flux will be compared with the inputs from the tributaries. No recent air phase PCB measurements exists for the Bush River region.

Monitoring will begin with sites in various parts of the Bush's river non-tidal streams (**Figure 1**) with additional samples in the upstream locations to track down potential source areas for PCBs. The list of potential streams and specific locations will be determined based on prior data collected in this watershed by UMBC and after consultation with representatives from the County and MDE. A preliminary list of streams includes:

- Winter Run
- Bynum Run
- James Run
- Grays Run

Additional locations will be included in the tidal area of the streams above and in the Bush River itself to compare watershed concentration with the river concentration, as well as in the boundary between Bush River and Chesapeake Bay main stem to estimate the load from Bush River into the Chesapeake Bay. Additional sites will be located in the proximity of the major NPDES (regulated runoff or WWTPs) to estimate their contribution to the PCB loading will be discussed. The list of possible locations is summarized in Table 1 and shown in Figure 1.

Table 1 list of possible location for monitoring PCB level

Stream	Location	Tidal
Lower Winter Run	LWR1	NO
Lower Winter Run	BUR5	Yes
Bynum Run	BYR1, plus one upstream, to be specified	NO
Bynum Run	To be specified	Yes
James Run	To be specified	NO
Grays Run	BUR7, BUR8	NO
Grays Run	BUR6	YES
Bush River	BUR4, BUR3, BUR2	YES
Chesapeake Bay	BUR1	YES
NPDES stormwater	To be specified	To be specified
NPDES WWTP	To be specified	To be specified

Data Interpretation and Reporting

Results from this study will be used to identify potential major sources of PCBs in the Bush River. Dissolved and total PCB loads from each of the streams will be calculated and compared with each other. In addition, these loads will be compared with the estimated exchange with the air phase and flux from bottom sediments in the river. The following questions will be addressed in the data interpretation:

1) What is the current loading of PCBs from each of the identified sub-watersheds and how much do they contribute to the existing PCB water concentrations in the Bush River?

2) Which of the three streams is the primary contributor of PCB loading to Bush River?

3) How does the PCB loading from streams compare with loading from the air phase?

4) How does the PCB loading from streams compare with estimated loading from legacy sediments in the Bush River?

5) Is further study warranted to quantify the input of PCBs from contaminated sites within APG?

Material and Methods

Water column measurements

In this proposed work, a recently published guidance document on passive sampling (U.S. EPA/SERDP/ESTCP. 2017) will be followed to measure freely dissolved concentrations of PCBs in surface water. The sampling method would entail preparation of polyethylene passive sampling strips with performance reference compounds, placement at the selected locations after encasing in deployment devices as shown in **Figure 2**, retrieval after a 3 month period of deployment, extraction, analysis, and interpretation of the results. Passive samplers will be prepared using 1 g of 51 µm thick polyethylene sheets encased in stainless steel mesh. The samplers will be cleaned by solvent extraction followed by the impregnation with four PCB performance reference compounds in the laboratory. After retrieval of the passive samplers from the field, they will be cleaned on site using a clean tissue and DI water to remove surface contamination and placed into pre-cleaned 40 mL vials. All passive samplers will be placed into a cooler marked for return to UMBC. All samples will be stored at 4 ºC in closed glass vials until extraction. Extraction of all stored samples will be completed within 1 month of generation of the sample. Cleanup and analysis of passive samplers will follow methods described in the analytical section below. For each deployment, a set of three unexposed passive samplers will be extracted and measured to determine the initial concentration of the performance reference compounds and any background contamination. The loss of performance reference compounds during the deployment period will be used to correct for non-equilibrium as described in Fernandez et al. (2009).

Air concentration measurements

The air-phase concentration of PCBs will be calculated from the concentration measured in PE sheets exposed for 3 months in the passive air sampling units (**Figure 3**). The method will be based on the approach by Liu et al. (2015) where a range of performance reference compounds are pre-loaded in the sampling polymer and used to track the rate of exchange between air and passive sampler during the exposure period. This approach has led to accurate assessments of air phase concentrations of a wide range of semi-volatile organic compounds (Lohman, 2012;

Khairy and Lohmann 2012; McDonough et al. 2014) and was recently used by UMBC to monitor air concentration of PCBs and other pollutants in the DC area (Ghosh, 2019- DOEE interim report).

PCB extraction from passive samplers

Passive samplers will be extracted for PCBs using 30 mL additions of hexane then placed on an orbital shaker overnight. The solvent will be collected, and new solvent will be added. This process will be repeated three times.

PCB cleanup and analysis

PCB analytical methods for this project will follow the methods currently used for PCB measurements performed by UMBC for fish samples from the Maryland Department of Environment. The analytical methods are summarized below.

PCB cleanup is based on EPA publication SW-846 (Test Methods for Evaluating Solid Waste, Physical/Chemical Methods) methods 3630C (Silica gel cleanup) and 3660B (Sulfur removal with copper). In the silica gel cleanup process, the dried and concentrated extracts are passed through a 3% deactivated silica gel column for the removal of organic interferences and to separate the PCBs. Silica gel (chromatographic grade, 100-200 mesh, Fisher Scientific, Fair Lawn, NJ) is activated by heating at 130°C for 16 hours, then deactivated by gradually adding 3% by weight deionized water and rotating on a roller at approximately 2 rpm overnight. The sulfur cleanup procedure will be followed only when there is evidence of contamination from elemental sulfur. The two standard methods will be followed without any modifications.

PCB analysis will be performed on an Agilent 6890N gas chromatograph (Restek, Bellefonte, PA, USA) with an electron capture detector and a fused silica capillary column (Rtx-5MS, 60 m x 0.25 mm i.d, 0.25 ìm film thickness). PCB standards for calibration are purchased as hexane solutions from Ultra Scientific (North Kingstown, RI, USA). Internal standards, 2,4,6-trichlorobiphenyl (PCB 30) and 2,2',3,4,4',5,6,6'- octachlorobiphenyl (PCB 204) will be added to all samples. A total of about 129 most commonly found PCB congeners and congener groups are measured using this method. In some cases peaks coelute which are identified and reported as the sum of congeners. Detection limits for individual PCB congener in tissue samples range from 0.001 – 0.1 ng/g with lower detection limits for the more chlorinated congeners. Detection limits for water concentration using passive sampling range from 1-10 pg/L with lower detection limits for the higher chlorinated congeners. Further details and QAQC for the PCB analysis are available upon request.

TSS, POC, and DOC analysis

Grab water samples will be collected a total of 4 times during baseflow over the passive sampler deployment period of 3 months to measure total suspended solids (TSS), Particulate organic carbon (POC), and dissolved organic carbon (DOC). TSS will be analyzed gravimetrically. Suspended solids collected in a filter paper will be used to measure the organic carbon content. Organic carbon content of the TSS sample will be measured. DOC analysis will be performed using a Shimadzu Total Organic Carbon Analyzer (TOC-V CPH model) using the Non-Purgeable Organic Carbon (NPOC) mode and detection performed with a NDIR detector. The DOC analyzer will be calibrated before each set of measurements with standard solutions, and DOC standard reference will be run every set of measurements. Methods for these analyses will follow prior source tracking work performed in the Anacostia River tributaries (Ghosh et al. 2019).

Partitioning to dissolved organic carbon (DOC)

The concentration of pollutants associated with dissolved organic carbon will be calculated based on the measured freely dissolved concentration using equilibrium partitioning models. For PCBs and PAHs, the DOC-pollutant partitioning coefficients will be calculated using correlation from Burkhard (2000), which is applicable to naturally occurring DOC.

For PCBs: $\log \mathrm{K_{DOC}} = 0.71 \log \mathrm{K_{ow}} - 0.5$ $\quad (\mathrm{n} = 77,\ \mathrm{r}^2 = 0.69)$ – Equation (31)

For PAHs: $\log \mathrm{K_{DOC}} = 1.18 \log \mathrm{K_{ow}} - 1.56$ $\quad (\mathrm{n} = 33,\ \mathrm{r}^2 = 0.76)$ – Equation (32)

For pesticides, the correlation reported by Li et al. (2015) was used and is shown below.

For OCPs: $\log \mathrm{K_{DOC}} = 0.333 \log \mathrm{K_{ow}} + 2.937$ $\quad (\mathrm{n} = 12,\ \mathrm{r}^2 = 0.82)$ – Equation (33)

In the above equations, K_{DOC} is the partitioning coefficient between DOC-associated and freely-dissolved pollutant concentration (L/kg) and K_{ow} is the octanol-water partitioning coefficient for the pollutant.

Partitioning to particulate organic carbon (POC)

For partitioning to particulate organic carbon, the following correlation reported by DiToro et al. (1991) will be used for PCBs, PAHs, and pesticides.

$\log \mathrm{K_{OC}} = 0.983 \log \mathrm{K_{ow}} + 0.00028$ – Equation (34)

Where, K_{OC} is the partitioning coefficient between POC-associated and freely-dissolved pollutant concentration (L/kg) and K_{ow} is the octanol-water partitioning coefficient for the pollutant.

Pollutant loading calculations

At base conditions, freely-dissolved pollutant concentrations measured by passive sampling will be used in conjunction with the equilibrium partitioning models described below to calculate the total concentration of the pollutants as shown below:

$\mathrm{C_{Total}} = \mathrm{C_{Free}} + \mathrm{C_{DOC}} + \mathrm{C_{POC}}$ – Equation (35)

Where:

- C_{free} is the freely dissolved concentration of the pollutant (ng/L)
- C_{DOC} is the DOC-associated concentration of the pollutant (ng/L)

- C_{POC} is the POC-associated concentration of the pollutant (ng/L)

C_{DOC} and C_{POC} were calculated using the following equations:

$$C_{DOC} = C_{Free} \times [DOC] \times K_{DOC} \qquad \text{– Equation (36)}$$

where, [DOC] is tributary-specific average DOC concentration (kg/L), from samples collected during passive sampler deployments.

$$C_{POC} = C_{Free} \times f_{OC} \times \frac{SS_{Base}}{V_{Base}} \times K_{OC} \qquad \text{– Equation (37)}$$

Where:

- f_{OC} is the tributary-specific average organic carbon fraction on suspended solids, for samples collected during passive sampler deployments
- SS_{Base} is the total mass of suspended sediment transported at base flow conditions over the deployment period (kg)
- V_{Base} is the total volume of water carried at base flow conditions over the deployment period (L)

Combining equations (35), (36) and (37), the total pollutant concentration (ng/L) will be calculated as:

$$C_{Total} = C_{Free} \times \left\{1 + ([DOC] * K_{DOC}) + \left(f_{OC} * \frac{SS_{Base}}{V_{Base}} * K_{OC}\right)\right\} \qquad \text{– Equation (38)}$$

The total pollutant loading M (g), will be calculated as:

$$M = C_{Total} \times V \qquad \text{– Equation (39)}$$

Where, V is the total discharge volume

Budget

The tasks outlined above will be carried out by a team of personnel from UMBC including a Ph.D. student, an undergraduate student, and a post-doctoral associate. The team will be supervised by PI, Dr. Upal Ghosh. The budget estimated here is for a single sampling campaign with data analysis and reporting as described above.

Category	**Year 1**
Salary + fringe	$44,584
Supplies	$6,520
Travel	$1,000
Student tuition and insurance	$3,706
Total Direct	$55,810
Total Indirect	$28,940
TOTAL	**$84,750**

A breakup of the costs based on major task category is provided below.

Task	**# of samples**	**Cost $**	**Description**
Passive samplers prep and analysis	30	21,000	Surface water and sediment porewater at each of 14 locations plus duplicate at one location; PCB analysis
Sediment samples	15	3,750	1 at each location; PCB and TOC
Water quality measurement	15	9,000	1 at each location (TSS, TOC, POC) 4 times
Air samplers	2	2000	Gas phase PCB measurement
7 field trips by 2-3 people	7	28,000	(1 initial site survey, 2 trips each for deployment and retrieval, 2 intermediate for water quality sampling)
Data interpretation and reporting		21,000	(Freely dissolved and total PCB calculations, loading calculations, flux calculations, reporting)
TOTAL:		**84,750**	

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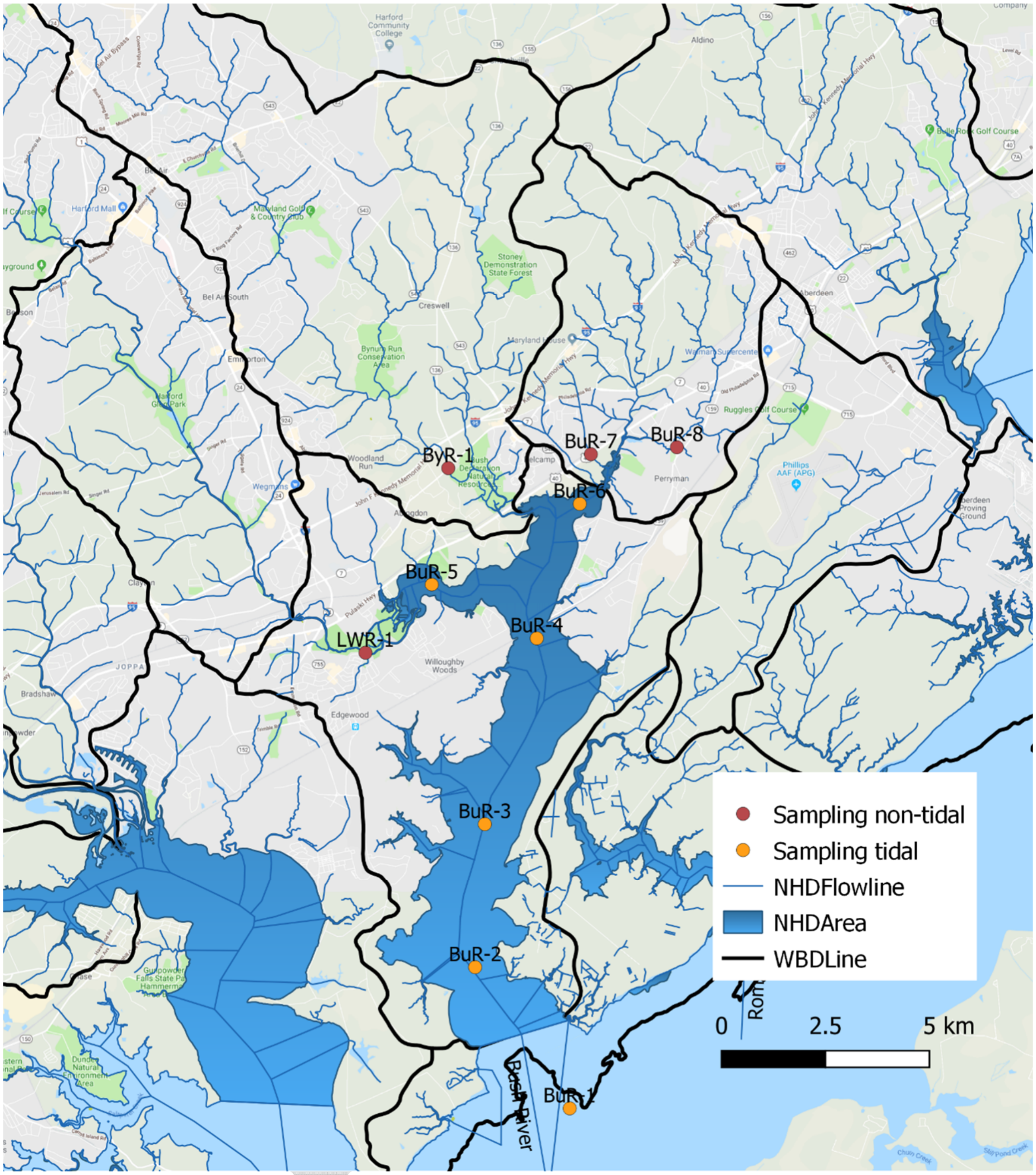

Figure 1: Map of passive sampling in the Bush river Watershed. Passive samplers will be deployed at the previous MDE locations in Lower Winter run (LWR), Bynum Run (BYR), Gray run (BUR7,8) watershed and in the tidal part of the stream in the Bush River. Additional samplers will be added upstream of Bynum Run and its tidal part, as well as near major NPDE (to be determined).WBD: watershed boundary line shown in black, NHD: National Hydrography Dataset.

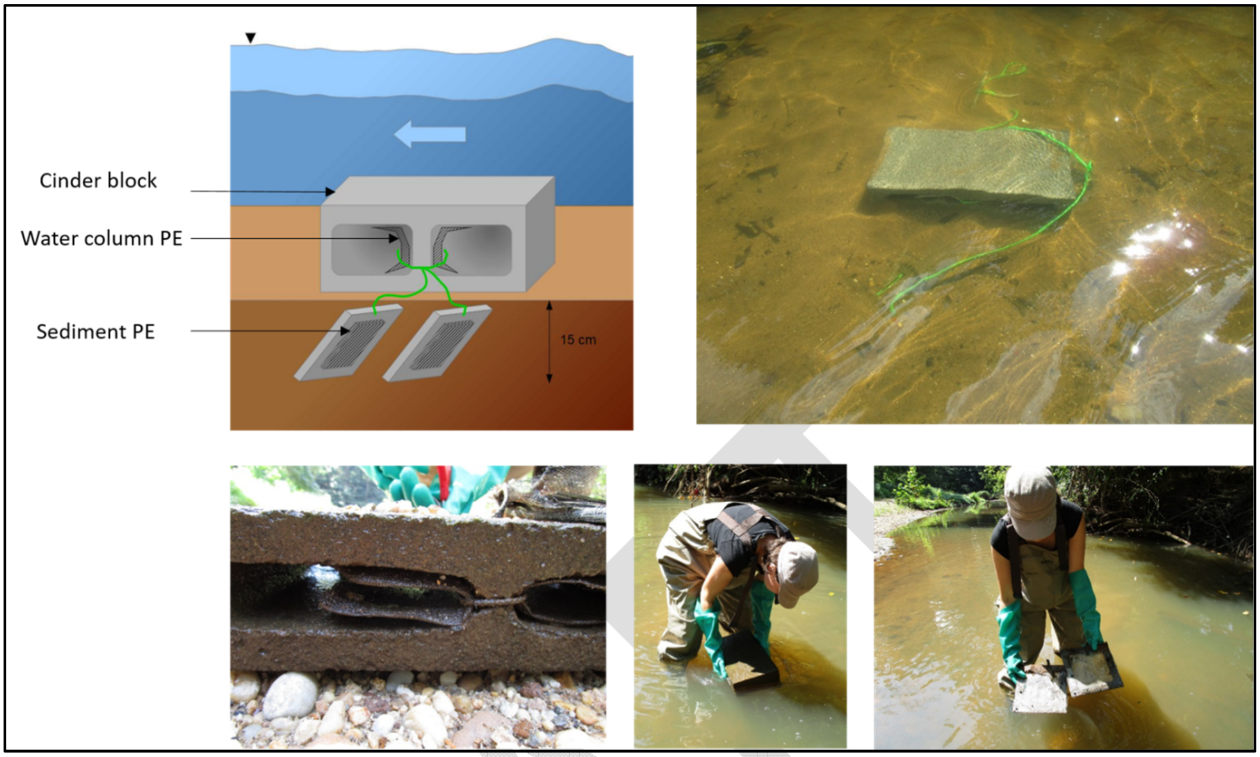

Figure 2: Passive sampler deployment in streams. Polyethylene (PE) sheets were enclosed in stainless steel mesh and were inserted inside a cinder block to measure water column concentration, or mounted into frames and inserted into sediments to measure sediment porewater concentration. Top left: a schematic representation of passive sampler deployment *in situ*. Top right: picture of passive sampler deployment in Anacostia tributaries. Bottom left: picture of water column PE inside cinder block. Bottom middle: cinder block containing water column PE is placed on the tributary bed, parallel to water flow. Bottom right: pictures of frames that are inserted into sediments to measure sediment porewater concentration.

Figure 3: Passive air samplers deployed on the rooftop at the River Terrace location. The passive sampling polymer medium is enclosed within the bowl-shaped enclosure to protect the polymer from direct deposition and influence of solar radiation. Passive air samplers deployed on the rooftop at the River Terrace location.